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Nicolas Copernicus and an Infinite Universe

By GRANT McCOLLEY

For many decades the historians of science have heralded Giordano Bruno as the first to advocate the ancient doctrine of an infinite universe as a corollary to the Copernican theory.[1] Recently this credit given to Bruno has been challenged, and the honor of originating the idea of an infinite universe claimed for Thomas Digges in his *A Perfit Description of the Caelestiall Orbes*.[2] There is, I believe, little doubt but that each of these men made an important contribution in expanding or popularizing the conception, and for this contribution each should be accorded a fitting place in the history of ideas. However, it is at best inappropriate to confer upon either the honor of first presenting the conception of an infinite universe as a corollary to, or as a part of the new world system. This was the achievement of the author of that system, Nicolas Copernicus.

As a rapid glance at any half-dozen pertinent discussions will show, it has long been our custom to say that in his world plan Copernicus retains the eighth sphere of the Ptolemaic scheme as the boundary of the universe. Less frequent, but nevertheless common, is the assertion that he thought of the fixed stars as located on the surface of this sphere.[3] Both statements are erroneous, as is their necessary implication that the world of Copernicus is finite. Not only does the author of the heliocentric theory state plainly to his age his belief in an infinite universe, but he definitely presupposes and employs such a universe in constructing his system of the world.

Before discussing in *De Revolutionibus* the problem of the extent of the universe, Copernicus treats briefly in Chapters I to IV, Book I, the conventional topics of the sphericity of the world, of the earth, and of the movements of heavenly bodies. Chapter V departs from tradition, and joins to the commonplace theme of the situation of the earth the proposition that our globe is qualified for circular motion. In Chapter VI this departure becomes more marked, and under the conventional heading, "Of the Immensity of Heaven in Comparison to the Magnitude of the Earth," the discussion concerns itself primarily with two unorthodox beliefs. These conceptions, so closely associated as to be virtually inter-related, are that the earth rotates diurnally and that the extent of the heaven is apparently infinite and unknown. The objective towards which the author is moving is proof of the infinity of heaven, acceptance of which would in turn prove the diurnal rotation of the earth.

This chapter opens with the presentation of mathematical proof of the vastness of the universe, from which Copernicus concludes that it seems certain that heaven is immense in comparison with the earth and that it has the appearance of an infinite magnitude. According to the estimation of the senses, he continues, the earth is in respect to the sky as a point to a body, and a finite to an infinite magnitude. This comparison of point to body is definitely conventional, but finite to infinite is quite the contrary. It is astonishing, then says Copernicus, that instead of the small earth, the vastness of the heaven is able to rotate in the space of twenty-four hours. He next provides additional mathematical proof of the greatness of the universe, and again concludes, with infinite changed to *indefinite,* that this evidence has shown nothing other than that heaven is of unmeasurable magnitude in comparison to the earth. It is not known, he adds significantly, how far this immensity extends itself.

In Chapter VII the theme of infinity is omitted, with the discussion consisting of attacks upon the Aristotelian conception of gravity, levity, and simple motion, and the Ptolemaic argument that rotation of the earth would cause it to fall to pieces, and clouds, birds, and falling stones to move westward. Chapter VIII continues the refutation of this argument from Ptolemy, with emphasis upon his contention that rotation of the earth, being a "violent" and not a "natural" movement, would cause the globe to be scattered. In the presentation of his complete answer to this belief, Copernicus once more links the idea of an infinite heaven or universe with the diurnal rotation of the earth.

Before this connection is made, however, the author points out and develops the argument that if centrifugal force would cause the rotating earth to expand and fly to pieces, revolution of the far greater heaven would cause it to dissolve into infinity. As the effect of this motion expands heaven to the heights, he reasons, the swifter must be its motion, for the extent of the circumference to be traversed in twenty-four hours will always be increasing. In turn, the accelerated motion increases the immensity of the heaven. Thus velocity increases magnitude and magnitude increases motion to infinity. At this point Copernicus injects the axiom of physics that what is infinite may neither be traversed nor moved, and concludes that heaven must of necessity stand.

Having proved by dialectic, according to Ptolemy and an accepted axiom of physics, that if heaven moves it is infinite, and if it is infinite it cannot move, Copernicus begins a transition to his plea for the existence of an infinite universe. "They" say, he continues, that beyond heaven there cannot be body, place, or vacuum, and that nothing can go out of heaven. Truly, he adds ironically, it is wonderful, if something may be restrained by nothing. Yet, if heaven were infinite, and only the interior concavity finite, so that everything will be contained within it, regardless of the magnitude it occupies, much more perhaps could it be verified that without heaven is nothing. It is next stated that heaven

remains immobile, and that the most important reason supporting the belief that the world is finite is motion. The conclusion is absent from this deduction, and the order of the parts reversed, but the implication is obvious.

After thus proposing an infinite universe as both a proper conception of the cosmos and a solution of the dilemma into which he has led the Aristotelians, Copernicus suggests that the question of the infinity of the heaven be left to the physicists, it being understood that the rotating earth is finite. This statement, which some historians have taken from its context and have presented as the ultimate conclusion, is clearly rhetorical, for in the next sentence Copernicus asserts emphatically, although indirectly, his belief that the universe is infinite. Why, he queries, have we hesitated until now to grant to the earth the mobility in keeping with its form, all for the reason that the world, whose end (*finis*) is unknown and cannot be known may fall down? A world whose end is described as unknown and not to be known is scarcely one that is regarded as a bounded and finite universe.

As we have noted above, Copernicus has said that it is an axiom of physics that what is infinite cannot be moved. In Chapter X of Book I, "De Ordine Caelestivm Orbivm," he employs this axiom in support of the system of the universe which he is developing: "Prima et suprema omnium est stellarum fixarum sphaera, se ipsam et omnia continens, ideoque immobilis"—First and above all is the sphere of the fixed stars, containing itself and all, and for that reason immobile.[4] What is infinite cannot be moved, asserts the quoted axiom. For the reason that it contains all things, the sphere of the fixed stars cannot be moved, says Copernicus. The immobility of this all-containing sphere, in effect the universe, is thus proved by its infinity.

In these various statements regarding the nature of the world, Copernicus has clearly indicated his belief in the infinity of the universe, and in addition employs such a universe as a basis for proving the diurnal rotation of the earth and immobility of the heaven. In his comparison of the magnitude of the earth to that of heaven, the latter is twice described as infinite, once as *indefinite,* and its extent is declared unestablished. Furthermore, he proposes the belief that heaven is infinite, and only the interior concavity finite. The principal reason for considering the world finite, he adds, is (its) motion, but this it does not possess. The limit of heaven, once described only as unknown, is now said to be both unknown and not to be known. In finale, the sphere of the fixed stars is held to be immobile because it contains, not only itself, but all things—in short, because it is a containing and unbounded extension.[5] One may not say that this universe, whose end is described as unknown and unknowable, is mathematically infinite. However, it is an infinite universe in the usual, non-technical meaning of the word: that which is immeasurable, indefinitely extended, and without actual or conceivable bounds in magnitude.

In further support of the belief that such a universe is a portion of the world of *De Revolutionibus,* three arguments may be advanced: first, Copernicus was familiar with the belief that the universe is infinite; second, he was aware that proof of such a universe was the most effective argument which he could employ to support the diurnal rotation of the earth; third, Copernicus was interpreted as presenting and supporting an infinite eighth sphere by five writers of standing, each of whom wrote in Latin, was conversant with *De Revolutionibus,* and, in addition, was thoroughly at home among cosmological and philosophic conceptions of the Sixteenth Century.

The first of these points, if not obvious, is made so by the fact that Copernicus quotes in Book I, Chapter viii, from the argument by which Aristotle and his commentators sought to prove that the world is not infinite, but rather is one and finite.[6] Among many others who discuss in detail the idea of the infinity of the universe are Thomas Aquinas and Albertus Magnus, not to mention Nicolas of Cusa.[7] As Pierre Duhem has shown, the closely related conception of a plurality and infinity of worlds was definitely active during the Thirteenth and Fourteenth Centuries, and was existent at the time of Copernicus.[8] Plutarch, Eusebius, and other historians of the Greeks were easily available. As a churchman and astronomer, the author of *De Revolutionibus* could not have been other than well acquainted with the belief that the universe is infinite.

During the age of Copernicus, and for centuries before it, the principal argument in support of a finite world was the assumption that the heaven revolves, and the axiom that what is infinite cannot be moved. This axiom, as Kepler mentions later, was of high authority, and, were heaven shown to be infinite, would become a powerful proof of the rotation of the earth.[9] For the Sixteenth Century, it was the most effective argument to be had.[10] That Copernicus was aware of its power is indicated by the emphasis which he places upon it. As mentioned above, he adds to the conventional statement that earth is a point in comparison with heaven, the declaration that heaven is infinite, indefinite, and its extent unestablished. In I, viii, he shows through Ptolemy that heaven is infinite. Having demonstrated both by his argument and that of the opposition that the world is without bounds, he applies the axiom and declares that heaven stands. He then further supports his contention that heaven is boundless by asserting it is a marvel that something can be restrained by nothing, and in I, x, without restating it, again applies the axiom in *ideoque immobilis.*

Of perhaps greatest importance is the last of the three arguments, that Copernicus was interpreted by informed men as supporting and advancing the conception of an infinite eighth sphere. The earliest of these men is Thomas Digges, whose *A Perfit Description* presents faithfully, by diagram and text, the infinite heaven and finite interior concavity of Copernicus.[11] That Digges is summarizing *De Revolutionibus*

is assured by the similarity between it and his digest, and by four statements to this effect which he includes in it.[12] Furthermore, all references to the universe as infinite fall within the last two-thirds of *A Perfit Description,* where Digges turns, as he states, from a general discussion of astronomy to an exposition of *"Copernicus* in hys Reuolutions."[13] The two references made to the eighth sphere in the first third of the work do not describe it as infinite, although the latter of these statements provides an ideal opportunity: "And the distance of the earth from the Sunne . . . yf it be referred to the Orbe of starres fixed, then hath it no proportion sensible."[14] It also appears from the able analysis made of Digges' remaining works by Messrs. Johnson and Larkey, that none of these contain statements or speculations as to whether or not the universe is infinite.[15] Under these conditions we have no grounds for assuming that the infinite eighth sphere of Digges' digest came from any source other than Copernicus. Since the author of *A Perfit Description* was an able astronomer of high reputation,[16] he was in position to evaluate accurately the universe presented in *De Revolutionibus,* and his interpretation of it as infinite merits respect.

A second ascription occurs in *De Stella Nova in Pede Serpentarii.* Kepler has found that belief in a *"fixarum infinitate"* leads to unfortunate consequences, and declares that we must tear out, if possible, this conception. He then places the blame for its appearance and continuance upon the axiom that what is infinite cannot be moved, and in identifying this axiom, states that the eighth sphere of *De Revolutionibus* is infinite. This infinite fixed sphere, he says, has come principally from that argument by which Aristotle demonstrated the world to be infinite through motion, and Copernicus, by removing motion, showed (*patiatur*) the eighth sphere to be infinite.[17]

In *De Magnete* of William Gilbert there is no direct statement that the eighth sphere of Copernicus is infinite. The evidence of this work is that Gilbert regarded this sphere as infinite, and, with some additions, follows and presents the arguments of *De Revolutionibus.* He states emphatically that "There cannot be diurnal motion of infinity or of an infinite body, nor therefore of this immeasurable *primum mobile."* This is the contention of Copernicus, with the difference that Gilbert applies the axiom to the sphere assumed to encircle the fixed stars, rather than to the latter, as did Copernicus.[18]

Prior to presenting this point and other arguments for the diurnal rotation of the earth, Gilbert states that Copernicus has illustrated the phenomena of bodies in motion with new hypotheses. Without mentioning other astronomers, he asserts that an ancient opinion, now developed by great thinkers, is that the whole earth turns in diurnal rotation. Among others, he then makes the point of the magnitude of the heavens, and contends that there cannot be diurnal motion of an infinite body. He employs with Copernicus the term *ineffabili* in describing the motion of the Ptolemaic eighth sphere, and follows him to say that

Ptolemy was over-timid in believing rotation would shatter the earth, and that he should rather have apprehended universal ruin and dissolution in the heavens. Again in the manner of Copernicus, Gilbert states that "Nature would seem to have given a motion in harmony with the shape of the earth, for the earth being a globe, it is far easier and more fitting that it should revolve on its natural poles, than that the whole universe, whose bounds we know not nor can know, should be whirled round." In this passage Gilbert writes, *"mundus, cuius finis ignoratur, scirique nequit";* Copernicus had written: *"mundus, cuius finis ignoratur, scirique nequit."*[19] The source of Gilbert's infinite universe is obviously Copernicus, whom he specifically mentions, and whose arguments he employs, even to the extent of taking word for word the important statement that the limit of the world is not known and cannot be known.

The two last of the five authors mentioned above are Julius Caesar la Galla and Giovanni Battista Riccioli, both of whom present and discuss in detail the arguments of Copernicus in support of an infinite eighth sphere. La Galla opens his extended discussion of *De Revolutionibus* with a criticism of the annual motion, subsequent to which the diurnal is considered. He digests carefully the reasoning and conclusions presented in I, viii, and points out that, according to Copernicus, it is better to regard the universe as infinite than finite. La Galla then pursues the argument of *De Revolutionibus,* and finds that it leads to the position that heaven is infinite.[20]

In the important *Almagestvm Novvm* of Giovanni Riccioli, the author of *De Revolutionibus* is again interpreted as advocating an infinite universe. It is significant that discussion of the various conceptions of infinity presented by Riccioli does not open with the Greeks, who are relegated to the subsequent section, but with the work of Copernicus. Not only is the initial section given over to an exposition and criticism of his views regarding infinity but, in the third and fourth sections of the chapter, these are again discussed both separately and in combination with those of other Copernicans, including William Gilbert "lib. 6. de Magnete cap. 3." Riccioli opens his discussion by proposing to refute the argument for the infinity of the world which Copernicus cited (*tetigit*) in Book I, Chapter viii. He then quotes from this chapter the portion which begins with the axiom that what is infinite cannot be moved, and closes with the query, why have we hesitated until now to give to the earth the mobility in keeping with its form . . . After a limited criticism, Riccioli concludes this section with the statement that physics and mathematics, and not physics alone here teach the infinity of the world or of the highest heaven. A second comment again refers to the conception of Copernicus as that of an infinite universe, or of an infinite sphere of the fixed stars.[21]

In the above discussion, evidence has been presented to show that Copernicus describes the eighth sphere as infinite, indefinite, of unknown

extent, and that by means of comparisons between heaven and earth, and by employment of a principle of Ptolemy, the eighth sphere is said to be infinite. He questions the belief that heaven can contain the stars, and proposes as a more credible theory the conception that it is infinite, with only the interior concavity finite, and concludes this passage with the assertion that the end of the world is not known and cannot be known. This much having been said, it is later held that, for the reason that the eighth sphere contains itself and all things, it is immobile. By means of supplementary supporting evidence, it was indicated that Copernicus was acquainted with the idea of the infinity of the universe, and that this idea was a commonplace to a well-read student. A second supplementary argument advanced the opinion that to the Sixteenth Century the most effective proof of the diurnal rotation of the earth was the infinity of heaven.[22] The last section of supporting evidence presented interpretations made by five competent authors. Each of these men knew the work of Copernicus at first hand, wrote in Latin, as did Copernicus, shared his background of ideas, and found in *De Revolutionibus* the conception that the eighth sphere is infinite.

Such evidence points directly to the conclusion that the universe of Copernicus should be so considered. It does not, unfortunately, indicate the exact interpretation which he and his commentators gave to infinity. Obviously their meaning was not that of the modern astronomer or mathematician, whose conception, in turn, may or may not be valid four centuries hence. On the basis of contemporary beliefs, it appears that infinite meant as much to Copernicus, Digges, Kepler, Gilbert, la Galla, and Riccioli as cosmological infinity could mean at that time. Such an interpretation as they employed is that now commonly given in non-technical discussions: unmeasurable, indefinitely extended, and without actual or conceivable bounds in magnitude.

A question of major importance remains. Did Copernicus truly believe, as he states, that the end of the universe cannot be known, or, did he take this position only to employ the axiom that what is infinite cannot be moved, and, by thus proving the immobility of the eighth sphere, to demonstrate in turn the diurnal rotation of the earth? It is my conviction that he was honest in his statements, and that this was not the case. Influential writers before him had believed in the infinity of the universe as well as in the motion of the earth, and his successful development of the second opinion would scarcely prejudice him against the first. Indeed, the apparent absence of stellar parallax would suggest the credibility of the belief that the bounds of the universe are unknowable.

As no less discerning a mathematician and historian than Riccioli has noted, the "opinion of Copernicus, inasmuch as it is in itself that of the infinity of the world . . . strongly aids the hypothesis of the annual motion of the earth."[23] A conception which supports an hypothesis is a conception which would enter into its formulation. It may be said,

I believe, that Copernicus was sincere in the statements quoted, and that to him belongs the honor of making an infinite universe an integral part of the heliocentric world order. By way of epilogue, it is suggested that his conception of the universe as boundless perhaps played a more fundamental role in bringing forth *De Revolutionibus* than heretofore has been considered possible.

REFERENCES.

1. I wish to acknowledge the courteous advice extended by Dr. David Rubio of Catholic University in connection with the interpretation of a number of the passages cited from *De Revolutionibus.*
2. Francis R. Johnson and Sanford V. Larkey, "Thomas Digges, the Copernican System, and the Idea of the Infinity of the Universe in 1576," *Huntington Library Bulletin,* V (April, 1934), 69-117. This valuable study of the astronomical contribution of Digges contains a reprint of *A Perfit Description,* to which reprint all citations of this work are made, and includes in addition a slightly reduced facsimile of the author's diagram of an infinite heliocentric system. As the present analysis implies, this study of Digges' contribution follows the conventional interpretation of the Copernican universe, and overlooks the fact that Digges, as he himself states (*loc. cit.,* p. 89), is presenting in *A Perfit Description* a non-mathematical digest of the work of Copernicus. As a result, the conception of infinity taken from *De Revolutionibus* has been credited to Thomas Digges.
3. Representative statements illustrative of such interpretations will be found in the "Thomas Digges," of Messrs. Johnson and Larkey (*loc. cit.,* pp. 72, 96, 115), and Sir William Dampier, *A History of Science* (Cambridge, 1932, p. 122). So far as the placing of stars on the surface of the eighth sphere is concerned, it should be noted that Copernicus does not so state, and that the diagram of his system included in *De Revolutionibus* (Book I, Chapter 10), depicts this sphere by means of the same type of circle employed for the orbits of the planets, that it contains no representations of stars, and bears the legend: "Stellarum fixarum sphaera immobilis."
4. In the *Commentariolus* (reprinted by Leopold Prowe, *Nicolaus Coppernicus,* Berlin, 1884, II, 188), Copernicus states of the sphere of the fixed stars: Summus est stellarum fixarum immobilis et omnia continens et locans." The substitution of *ideoque immobilis* for *locans* possibly may imply, although the evidence is too slight to support any conclusion, that Copernicus developed his conception of the universe as infinite after he had written the *Commentariolus.*
5. A possible interpretation of *continens* is *enclosing,* in which case Copernicus states, "first and highest of all is the sphere of the fixed stars, enclosing itself and all, and therefore immovable." However, this construction forces the normal meaning of *continens,* and, in addition, causes Copernicus to say that the eighth sphere is immobile because it bounds itself and the planets. Such a statement is meaningless and contradictory to the argument presented in Chapter VIII.
6. *De Caelo,* I, 5, 9.
7. Thomas Aquinas: *De Caelo et Mundo,* I, x-xv; Albertus Magnus: *De Caelo et Mundo,* I, ii, 1-8; Nicolas of Cusa: *De Docta Ignorantia,* II, xii.
8. *Léonard de Vinci,* Paris, 1906-1909-1913.
9. For Kepler's statement, see the discussion of his comment given below.
10. Prior to Copernicus, the most influential argument was the axiom that nature does nothing the more difficult way, and that the small earth should turn and not the immense heaven. I mention this argument briefly in "The Theory of the Diurnal Rotation of the Earth," forthcoming in *Isis.*
11. Digges frequently reiterates the statements of Copernicus regarding infinity, expands them somewhat, and makes some additions. Of the additions the most outstanding occur in the legend of the diagram (*loc. cit.,* p. 78), which describes the stars of the outer sphere as far excelling the sun in quantity and quality, and this infinite orb as the court of celestial angels and the

"habitacle" for the Elect (on p. 89 as the court of God). He follows Copernicus (I, i and x) by describing the infinite world as spherical (diagram, and *loc. cit.*, p. 88).

12. *Ibid.*, Preface, "To the Reader"; p. 86; p. 89; p. 95.
13. *Ibid.*, p. 86.
14. *Ibid.*, p. 86.
15. *Ibid.*, see especially pp. 95 and 111.
16. *Ibid.*, pp. 109 and 114. The contemporaries of Digges apparently understood him to be presenting Copernicus, for despite the six printings of *A Perfit Description* between 1576 and 1605, the painstaking search of Messrs. Johnson and Larkey has not revealed, nor have I been able to find, one reference connecting Thomas Digges with the infinity of the universe. Robert Burton (*Anatomy of Melancholy*, Preface, and "Air Rectified"), does not include him with Copernicus, Bruno, and others described as advocates of an infinite universe. Copernicus is so regarded in the Preface.
17. Chapter XXI. Kepler continues to include Bruno and Gilbert, who are again mentioned in the *Epitome*, Bruno at I, ii; Gilbert at I, v.
18. Book VI, Chapter iii. All following citations come from this book and chapter.
19. Book I, Chapter viii.
20. *De Phoenomenis in Orbe Lvnae* (Venice, 1612), Chapter vi. This work is reprinted in the national edition of the *Opera* of Galileo, III, i, 311-399.
21. Bononiae, 1651, II, 316; 317.
22. We have, I understand, no observational proof that it is the earth rather than the heaven which turns diurnally, and there was not available the post-telescopic analogy of the earth rotating in the manner of other globes.
23. Ed. cit., II, 317. As is stated, the reference of Riccioli is to the annual revolution of the earth.

SMITH COLLEGE, NORTHAMPTON, MASSACHUSETTS.

The Simpler Aspects of Celestial Mechanics

By HOMER A. HARVEY

(Fourth Paper)*

TIME

The subject of time, with its related problems of navigation and geodesy, is one of the most important in applied astronomy. A clear understanding of it depends upon a working conception of the celestial sphere in its daily and yearly motions about us. In this article we shall proceed from general principles to specific examples in such an order as to enable the student to grasp the fundamentals, and to carry out not only the observations upon which the calibration of timepieces depends, but also to make the necessary mathematical transformations to reduce his observations to practical results.

Of all celestial phenomena available as a master timepiece it might seem at first thought that the sun would be the most suitable, since it causes the sequence of daylight and darkness by which we live our daily routine. There are, however, several respects in which it fails to quality:

*For preceding papers, see February, April, and June-July (1936) issues of POPULAR ASTRONOMY.

(1) The exact instant of transit of the sun's center across the meridian cannot be determined, both for observational reasons and by reason of the fact that corrections are introduced which of themselves involve inaccuracies.

(2) The interval between transits varies from day to day and from season to season. This is due to two factors.

(a) Since the sun's motion in the ecliptic is the optical effect of the earth's motion in its orbit, its regularity, assuming that the rotation of the earth upon its axis is invariable, will depend upon the uniformity of the earth's orbital speed. Because of the ellipticity of the orbit this varies, in accordance with the principle that the radius vector, the line joining the earth and the sun, sweeps over equal areas in equal times and is therefore greater when the earth is near perihelion, or nearest to the sun, and less when it is near aphelion. As the result of this fact, considered alone, the sun would move eastward in the ecliptic, that is, increase in Right Ascension, most rapidly in winter and most slowly in summer, and the interval between transits would thus tend to grow longer in winter and shorter in summer.

(b) Since the regularity of transit depends upon the uniformity of "easting" made daily by the sun, from whatever cause, the inclination of the earth's orbital plane to that of the ecliptic introduces another source of variation. This can best be appreciated by studying a plane-surface map of the ecliptic and celestial equator, in which the ecliptic appears as a sinuous line about the straight line of the equator, as has been shown.* It is now obvious that, even assuming a uniform orbital speed, a greater daily easting will be made by the sun when in the neighborhood of the solstices, and less around the equinoxes, since the north and south component is reduced to its lowest values around the solstices. From this cause, considered independently, the day tends to become longer in summer and winter and shorter in autumn and spring.

Combination of the irregularities arising from the variation in orbital speed and the amount of daily easting of the sun among the stars gives rise to two maxima and two minima, with values up to about ± 15 minutes for the equation of time. It is apparent that, although this quantity is given in the *Ephemeris* for every day of the year with a relatively high degree of accuracy and the relation of the apparent and mean suns thus fixed satisfactorily for practical purposes, the astronomer must seek elsewhere for a better natural timepiece.

Such a phenomenon is at hand in the rotation of the earth upon its axis, which is practically invariable. Since we have extra-solar-system bodies as reference points for the purpose of recording this rotation, we are able to rid ourselves of the disturbing effects of orbital irregularity and axial inclination just described. We have thus in the rotating earth the most nearly perfect timepiece human ingenuity has discovered, and in the stars we have likewise a well-nigh perfect recording mechanism,

*Popular Astronomy, June-July, 1936, p. 302.

since their enormous distances from us preclude for the most part any observable effect of our 186,000,000-mile yearly shift in space. The slight errors arising from the proper motions of the stars themselves and the slow "precession of the equinoxes" can be accurately accounted for.

Thus a given star will transit our meridian at nearly precisely equal intervals, the "sidereal day," and, given the means of observing and recording this transit, the problem resolves itself into relating this sidereal day properly to the ordinary solar day by which we live.

As has already been stated, a clock rated so as to gain exactly one day a year over a solar timepiece is called a sidereal clock. Assuming such a clock to run perfectly, a given star will thus cross the meridian at the same clock-reading every day. Any deviation from the appointed time, as shown by comparison with the *Ephemeris,* is the clock's error.

The time of coincidence of the hour-circle of the vernal equinox with the meridian is taken as 0^h, sidereal time (S.T.). A star with a R.A. of 0^h therefore transits at 0^h S.T. Similarly, a star whose R.A. is $3^h\ 40^m$ transits at $3^h\ 40^m$ S.T. In general, *the sidereal time at the instant of transit of any given celestial body is equal to the right ascension of the body.* In the *Ephemeris* (pp. 262-558) will be found a list of so-called "clock-stars," arranged in the order of their right ascensions, and hence of their times of transit. The coördinates of these stars have been refined to high accuracy, corresponding to .001 sec. of time. The figures are given for every ten days, to allow for the slight irregularities already mentioned, and by interpolation the readings for any given day may be derived.

In observatory practice, transits are recorded by means of a telescope so mounted as to move in the meridian with any change in declination. In the field there are five or more vertical filaments with a single horizontal one bisecting the field. The central vertical filament lies in the meridian. Means are provided whereby the observer can record upon a moving drum the instant of transit of a star across the middle filament side by side with the oscillations of the pendulum of the master-clock. A trained observer can observe a transit within an error of a tenth of a second or so. By repeating observations this error may be greatly reduced by averaging. The error of the master clock is thus determined frequently, and the correct sidereal time is ascertained, which is transformed to solar mean time and broadcast throughout the country. This transformation will now be considered.

Reduction of Sidereal Time to Solar Time

As has been pointed out, with reasons given, a sidereal clock gains 3 minutes and 56.5 seconds a day over a solar clock. Assuming that they both have 24-hour dials, as indeed the sidereal clocks always have, the two clocks show the same reading once a year only—on or about September 23. The reason for this will be apparent when we consider

that the sidereal day begins when the vernal equinox is on the meridian, whereas the solar day begins at midnight. In order that the two clocks may show the same reading, therefore, the two celestial indicators, the sun and the vernal equinox, must be twelve hours apart in right ascension (vernal equinox 0^h, sun 12^h), a condition reached about September 23.

Reduction of sidereal time to local mean solar time becomes in principle, therefore, a process of *subtracting from the given sidereal time the amount of time lost by the solar clock since September 23.*

For example, it is desired to find approximately the solar time corresponding to $2^h\ 15^m$ S.T., June 7, 1936.

Days elapsed from September 23 to June 7 258
$3^m.942 \times 258 = 1017^m = 16^h\ 57^m$, time lost by solar clock since September 23.
$2^h\ 15^m\ (+24^h) - 16^h\ 57^m = 9^h\ 18^m$ .....Approximate mean solar time.

This result is necessarily only a fair approximation, for various reasons already pointed out. We may now consider a method of arriving at an accurate result.

In this method we shall make use of *Ephemeris* figures for the quantities involved. Since these are calculated for the meridian of Greenwich, it is obvious that we must take into consideration the position of our station with reference to Greenwich. Similarly, the figures are computed for 0^h Greenwich Mean Time (G.M.T.). Therefore, we must apply a correction for the time elapsed since 0^h. The reasons for these corrections must now be explained.

Suppose the longitude of our station is 78° 11′ 40″ W corresponding to $5^h\ 12^m\ 46^s$ of time (slow of Greenwich).

$$5^h\ 12^m\ 46^s = .2172 \text{ day.}$$
$$3^m.942 \times .2172 \times 60 = 51^s.3,$$

time gained by sidereal clock in given fraction of a day.

So that from 0^h in Greenwich to 0^h at a point in longitude 78° 11′ 40″ W, $5^h\ 12^m\ 46^s$ later, sidereal time will have gained an additional $51^s.3$ over solar time. This correction is thus *additive* to the sidereal time of 0^h Greenwich Mean Time, as given in the *Ephemeris,* for stations in *west* longitude.

In order to make plain the reason for the second correction to be applied to the time elapsed since midnight (0^h) at the local station, it will be well to examine the figure.

As indicated in the legend, our problem is to find the *solar* time interval required for the mean sun to move from position 1 to position 2. We find the *sidereal* time of position 1 for the given station by taking out from the *Ephemeris* the S.T. of position 1 for Greenwich, and applying the correction for longitude, as shown. The S.T. of position 2 is given by the terms of the problem. The sidereal interval from position 1 to position 2 is a mater of subtraction. This must now be converted into a *solar* interval, which will then be the solar time elapsed since midnight at the local station, in other words, the local mean time, which will be

the required answer. From the relation of 366¼ sidereal days to 365¼ solar days we derive the proper correction; this is shown in tabular form in Table 2 of the *Ephemeris* (pp. 735-737).

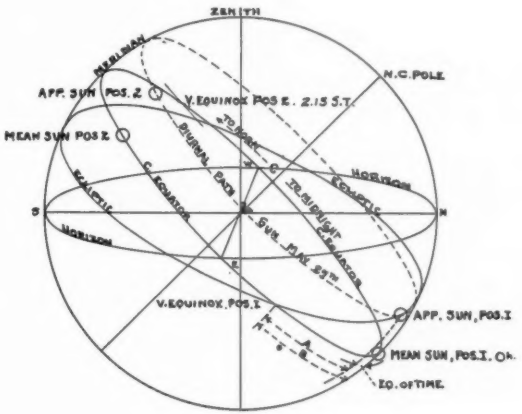


FIGURE 1.

The figure as drawn illustrates conditions about June 1 for a place in latitude 43° N. The mean time shown is midnight, (0^h). For Greenwich the *Ephemeris* gives all data calculated for this moment daily. For other longitudes, corrections must be applied. Vernal Equinox, position 1 shows its position at midnight, June 1. *A* is R.A. of Apparent sun, *B* is the R.A. of Mean sun. The difference between *A* and *B* is the Equation of Time, as shown. Since by definition the sidereal time is the hour angle of the Vernal Equinox, it will be seen that it is equal to the R.A. of the mean sun, *B*, plus 12 hours. The sidereal time of 0^h G.M.T. is given for every day in the year in the right-hand column of the left-hand pages in the *Ephemeris* of the sun.

Imagine the celestial sphere turning over the horizon, carrying with it the triad, Ver. Eq., Mean Sun and App. Sun, to the new positions as shown, position 2. The mean sun and the Ver. Eq. will follow the celestial equator, while the apparent sun will follow the dotted line as shown, parallel to the celestial equator. For the sake of clearness, the second position of the ecliptic is not shown, except the small section of it marking the new position of the vernal equinox. The app. sun, position 2, would of course lie upon it also.

In problems of conversion of Sidereal Time to Mean Solar Time, the S.T. of position 2 is given. The S.T. of position 1, derived from the *Ephemeris* for Greenwich and corrected for the longitude of the station, is first found. Then subtracting the S.T. of position 1 from the S.T. of position 2 will obviously give the "sidereal interval," the number of sidereal hours, elapsed since the triad was at position 1, namely midnight. This amount, converted into solar hours by use of the figures in Table 2 of the *Ephemeris* will be the solar time elapsed since the mean sun was in position 1. This is the required local mean time corresponding to the given S.T.

Now let us carry out our original problem using this exact method.

Example 1. At a local station in Long. 78° 11′ 40″ W, June 7, 1936, the sidereal time is $2^h\,15^m$. Required the Local Mean Time.

Solution:

S.T. of Greewich 0^h Mean Time (B+12^h, figure), taken from *Ephemeris* for June 7	17^h	0^m	51^s
Correction for longitude			+51.3
S.T. of 0^h. Local Mean Time (Pos. 1)	17	1	42.3
Given S.T. (24 hours added) (Pos. 2)	26	14	60
Subtract Pos. 1 from Pos. 2 (Sidereal Time interval)	9	13	17.7
Reduction to a solar time interval (Table 2)			−1 30.6
Local Mean Time	9	11	47.1

This compares fairly well with the approximate result of our first solution. It may be further converted into Eastern Standard Time (the time-belt of the given station) by adding the difference in time between that of the station and that of the 75th meridian.

75th Meridian slow of Greenwich	5^h		
Local station slow of Greenwich	5	12^m	46^s
Local station slow of 75th meridian		12^m	46^s
Local Mean Time (see above)	$9^h\,11^m\,47^s.1$		
	+12 46		
E. S. T.	$9^h\,24^m\,33^s.1$ Ans.		

Example 2. At the instant of the transit of Pollux on June 2, 1936, what is the Local Mean Time of a station in Long. 88° 40′ W.?

Pos.(2)	R.A. Pollux June 2, 1936, (*Eph.*, p. 416) which is local S.T. at time of transit. (Def.)	7^h	41^m	$25^s.7$
	S.T. of 0^h G.M.T., June 2	16	41	8
	Correction for 88° 40′ W. Longitude			+52.8
Pos.(1)	S.T. of local M.T. 0^h	16	42	6.2
	Subtracting (1) from (2)	14	59	19.5
	which is the sidereal interval since 0^h local M.T.			
	Corr. to reduce this interval to solar time interval (Table 2)			−2 27.3
		14^h	56^m	$52^s.2$

Equivalent to $2^h\,56^m\,52^s.2$ P.M. Local Mean Time.

For the amateur the important thing about this process of conversion of time is that, if he has circles on his telescope mounting so that he can use it for an improvised transit instrument, he may observe the transit of a star selected from the list in the *Ephemeris* (from the series beginning on p. 346, since the circumpolar stars are not suitable for the purpose) and determine his sidereal time at any moment he may choose, from which, by conversion, he may derive his local mean time with an error of only a few seconds. While his determinations will lack the high accuracy of the operations of the Naval Observatory with its precise instruments and trained observers, yet the principle is identical, and an uncertainty of a few seconds will be a small price to pay for the thrill of the discovery that he has at his command the most accurate timepiece

in existence, by whose testimony he may make bold to challenge the finest watch produced. If he knows his longitude accurately, he will also know the correction to apply to reduce his findings to the Standard Time of his time-belt, and thus check his watch or clock.

As I have stated before, any good clock rated so as to gain $3^m\ 56^s.5$ a day will serve admirably as a sidereal clock. In my own observatory I have devised a trigger release to hold the pendulum to one side until operated by a button at the telescope. If the clock has been running with moderate accuracy one knows the approximate Sidereal Time from its face, and it is simply a matter of refining the time shown so as to facilitate picking up celestial objects by the use of the circles. This process is as follows:

The star due to transit next (with a declination as near 0° as possible, since such stars move across the field most rapidly, as explained, and also afford the most comfortable position at the telescope) is selected from the *Ephemeris* list, and the clock hands set to conform to its R.A., to the nearest second. At the same time the transit instrument (telescope set in the meridian) is set to conform to the star's declination. The observer has then only to wait for the star to appear in the field, holding himself in readiness to start the clock on the correct time when the star transits the filament. The star is usually recognizable by its appearance and magnitude, as well as by the fact that it appears on the horizontal filament if the telescope is set accurately. The trigger is released at the instant of transit, and the clock is started on the correct S.T. Another transit may be taken of a later star to check the first reading. The clock readings will now enable the observer to use his circles for locating objects, as will be explained more in detail in a later paper. Its time may also be converted to watch time, as already explained. Having found the Standard Time, it may be transferred to one's watch with a little practice. The best plan is to select a time, say five minutes in advance of the sidereal clock reading, to allow for the calculation, and the corresponding watch reading is set on the watch as nearly as possible and the watch is stopped. When the clock reaches the selected moment, the watch is started.

If repeated setings show that his watch fails to agree with Western Union or radio time by a constant amount, the amateur will know from that fact that his telescope is out of the meridian by that amount, and repeated trials will presently bring it into line.

Finally, I may remind the amateur that all corrections for longitude in the United States will be plus, or additive to the S.T. of 0^h G.M.T., as taken from the last column on the left-hand pages in the ephemeris of the sun, and that all reductions of a sidereal time interval to a solar will be subtractive. With this in mind, the reduction of observational findings will become rapid and accurate with practice.

Our next paper will take up the problem of the computation of the local apparent time from a single reading of the elevation of a known

object above the horizon. The deduction of the longitude of the station by comparison of the local time thus found with the Greenwich Mean Time carried on a chronometer constitutes one of the most important duties of the navigator. Other means are available for determining longitude, such as graphic methods and the present-day radio methods. These, however, are not primarily astronomical processes, and may be left to the amateur's discretion.

Example 3 (to illustrate the Eq. of Time). When the center of the apparent sun is on the meridian, on June 2, 1936, what is the local *mean* time at a point in Long. 88° 30′ W?

Value of Eq. of Time at 0^h G.M.T. June 2, 1936 $+2^m\ 16^s$ (*Eph.* p. 8).
Daily change at same date, $-9^s.4$ (same column), 88° 30′ corresponds to $5^h\ 54^m$ in time.
$9.4 \times 5.9/24 = 2^s.31$, *decrease* in Eq. of Time at given Long.
$2^m\ 16^s - 2^s.31 = 2^m\ 13^s.69$, Eq. of Time at moment of observation at given station.

Time by apparent sun	$12^h\ 0^m\ 0^s$
Eq. of Time to be subtracted	$2\ 13.69$
Mean Time	$11^h\ 57^m\ 46^s.31$

A plus sign before the Eq. of Time means that the apparent sun is ahead (West) of the mean sun, and transits first. (*Eph.*, p. 819).

Example 4. What is the difference in local time between Albany, New York, (long. 73° 45′ 18″ W) and Chicago, Illinois, (long. 87° 36′ 54″ W?

$$\begin{array}{r} 87°\ 36'\ 54'' \\ 73\ \ 45\ \ 18 \\ \hline 13°\ 51'\ 36'' = 13°.86 \end{array}$$

$13°.86/15 = .924^h = 55^m\ 26^s$. Ans.

Example 5. What is the Eastern Standard Time at Albany, New York, when the L.M.T. (local mean time) is $10^h\ 46^m\ 32^s$ A.M.?

E.S.T. is the time of the 75° 0′ 0″ Meridian.
Longitude of Albany 73 45 18

Difference	1° 14′ 42″
Equivalent to $4^m\ 59^s$.	
Local Mean Time	$10^h\ 46^m\ 32^s$
Less	4 59
Required E.S.T.	$10^h\ 41^m\ 33^s$ A.M.

Example 6. When the time in Columbia, South Carolina, is $11^h\ 40^m$ A.M., L.M.T., what is the L.M.T. in Los Angeles, California? What is the air distance between these cities, the latitude of each being 34°?

Columbia, S. C., Long. 81° W. Los Angeles, Calif., 118° W.
Difference, 37° = $2^h\ 28^m$.
Subtracting $2^h\ 28^m$ from $11^h\ 40^m$, we have $9^h\ 12^m$ A.M. as the corresponding time in Los Angeles.
Length of degree of longitude at equator, 69.23 miles (*Eph.* p. xvi).
Cos 34° = .82904; $69.23 \times .82904 = 57.4$ miles, length of degree of longitude at latitude 34°.
$57.4 \text{ miles} \times 37 = 2123$ miles. Ans.

Example 7. In what latitude and longitude and on what date will Vega be in the zenith at midnight?

R.A. of Vega $18^h\ 34^m\ 45^s$ (Jan. 1. *Eph.*,p. 507).
Decl. of Vega +38° 43′ 21″ (Jan. 1. *Eph.*,p. 507).

According to the problem Vega is in the zenith, when the mean sun is at lower culmination. Vega must be 12^h in R.A. ahead (or west) of the sun.

Therefore the sun must be in R.A. $18^h\ 34^m\ 45^s$ minus $12^h = 6^h\ 34^m\ 45^s$.

From the following it is seen that this occurs on June 29.

R.A. sun June 29.0 $6^h\ 30^m\ 45^s$ G.M.T. 0^h. (*Eph.*, p. 8)
R.A. sun June 30.0 $6^h\ 34^m\ 53^s$ G.M.T. 0^h. (*Eph.*, p. 8)

Gain in R.A. for the day, 248 seconds.

$6^h\ 34^m\ 45^s$ minus $6^h\ 30^m\ 45^s = 4^m = 240$ seconds,

amount to be gained after 0^h, June 29, to reach desired R.A.

$240/248 \times 24^h = 23^h22$,

time elapsed after 0^h, June 29, when sun reaches desired R.A.

$23^h\ 13^m\ 12^s = 11^h\ 13^m\ 12^s$ P.M., G.M.T., June 29, 1936,

the instant when mean sun and Vega are 12 hours apart in R.A.

At this instant Vega will be $46^m\ 48^s$ east of the meridian at Greenwich.

Therefore at the corresponding longitude east Vega will be on the meridian; that is, 11° 42′ 00″ east of Greenwich.

To be in the zenith the latitude must equal the declination of Vega; i.e., +38° 43′ 21″. The required place is in Tunis, Northern Africa.

Example 8. In what longitude will Apparent and Mean Time agree at midnight in June, 1936, and what is the day of the month?

On reference to the *Ephemeris* we find that the Eq. of Time becomes zero some time on June 14, that is it changes algebraic sign. Our problem, therefore, is to determine how long after 0^h, June 14, the Eq. of Time becomes zero, and convert this time thus found into longitude.

Eq. of Time June 14.0 = $+2^s.77$ (*Eph.*, p. 8).

Decrease in Eq. of Time during the next 24 hours, $12^s.67$ (same col.).

Let x be the number of days required to bring the Eq. of Time to zero.

Then $12.67\ x = 2.77$; $x = .2187$ days $= 5^h\ 14^m\ 56^s$. This corresponds to 78° 44′ of longitude.

Therefore, on the meridian 78° 44′ west longitude the Eq. of Time will be zero at midnight, June 14, 1936; mean and apparent time will agree, because the mean and apparent suns will have the same R.A. Pittsburgh, Pennsylvania, lies near this meridian.

It is recommended that the student set himself a variety of examples involving the fundamental problem of time, and solve them by application of the principles laid down, with the aid of the figure. Only in this way will he acquire a clear conception of the mechanism. In the *Ephemeris*, pp. 817-821, will be found a short treatment of the subject, with illustrative examples. In recent editions of the *Ephemeris* correction has been made for nutation, but this for practical purposes may be omitted.

Batavia, New York.

The Sun's Orbital Motion

By PAUL D. JOSE

It is known that the center of mass of the solar system moves in and out of the sun; at times being as far as 700,000 kilometers above the surface. It seemed worth while to compute the positions of this point over a period of years and to represent the results graphically. In a preliminary study it was at once apparent that the smaller planets contribute little to the problem. The following table gives the positions of the center of mass of the sun and each planet, measured from the sun's center.

Planet	Mass ($\odot = 1$)	Mean Distance 10^6 kms	Mean Distance of Center of Mass of Sun and Planet from Center of Sun
Mercury	0.000,000,14	57.85	8 kms
Venus	0.000,002,46	108.10	266
Earth	0.000,003,03	149.45	453
Mars	0.000,000,32	227.72	73
Jupiter	0.000,954,79	777.6	741,736
Saturn	0.000,285,71	1,425.6	407,192
Uranus	0.000,043,73	2,868.1	125,416
Neptune	0.000,051,78	4,494.1	232,692

The sun's radius is 695,000 kms; hence as is pointed out in textbooks, only the center of mass of Jupiter and the sun lies outside the sun.

In this problem the bodies considered were: the sun, Jupiter, Saturn, Uranus, and Neptune. The time extends from 1840 to 1940. For the interval 1840 to 1904 the heliocentric x, y, z coördinates of the planets were computed from the longitudes and latitudes and radii vectores as given in the *British Almanac* and for the interval 1904 to 1940 the coördinates were taken directly from "Planetary Coördinates for the Years 1800-1940."

This latter publication does not give the coördinates of Uranus and Neptune before 1904; hence recourse was taken to the *British Almanac* for all data prior to that date. The coördinates of the center of mass were computed for January 1 and February 10 of the even years from 1840 to 1904 and for every 160 days for the remainder of the time. The formulae used were the well-known ones for the center of mass:

$$X = \Sigma m_i x_i / \Sigma m_i \qquad Y = \Sigma m_i y_i / \Sigma m_i \qquad Z = \Sigma m_i z_i / \Sigma m_i$$

where x_i, y_i, z_i are the heliocentric coördinates and m_i the masses of the planets. The denominators, of course, include the sun's mass.

As the center of mass of the solar system moves in a straight line through space and all the bodies move in orbits around it, the sun necessarily describes a small orbit. Figure 1 shows the path of the center of mass around the sun for the epoch 1904-1940. The curve is plotted from the x and y components (the z component is never large). The small circles are plotted for every 160 days. The heavy circle represents the sun's circumference. If the curve is rotated through 180°

around the origin of the axes, the result may be considered as the path of the sun around the center of mass. The lower curve of Figure 2 shows the distance of this point from the sun's center in units of 10^6 kms and gives the data over the one-hundred year period. The dotted line at 0.69×10^6 kms represents the sun's surface.

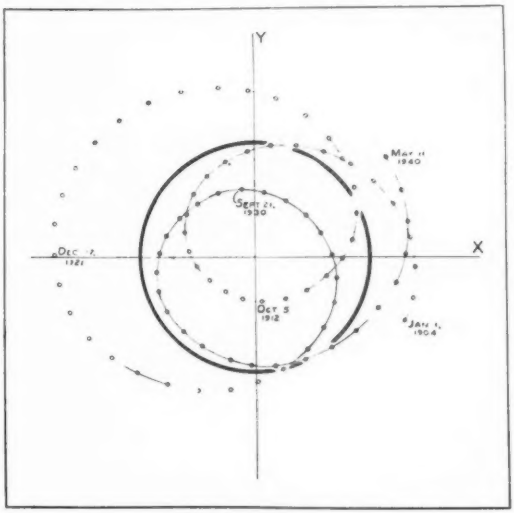


FIGURE 1

THE PATH OF THE CENTER OF MASS OF THE SOLAR SYSTEM REFERRED TO THE SUN.

From the shape of the curve it appeared that it might be interesting to compute the orbital "angular momentum" at intervals over the 100 years. The angle swept out between successive dates was computed from the formula

$$\cos \omega = (x_1x_2 + y_1y_2 + z_1z_2)/r_1r_2$$

By substituting the value of ω and the mean value of r_1 and r_2 in the formula

$$\text{Angular momentum} = kmr^2\omega$$

the ordinates of the "angular momentum" curve (Fig. 2) were obtained. k is a constant necessary to reduce the units employed to gm cm^2/sec. m is the mass of the sun. The ordinates are given in units of 10^{47} gm cm^2/sec.

The question immediately arises: is this an illusion due to a peculiar combination of the variable angular velocities and variable radii vectores of the sun about the center of mass of itself and the individual planets, or is it real? The extreme values in "angular momentum" in the interval 1904-1940 are 0.567×10^{47} (Feb., 1912) and 3.619×10^{47} (June,

1920). This variation of nearly seven-fold would be expected to produce some marked consequences if it were real. It is highly desirable to discover whether this is real or fictitious. Since the angular momentum of a system of bodies must remain constant it is tempting to speculate on a possible transfer of momentum, but before doing so another result of the calculations will be stated.

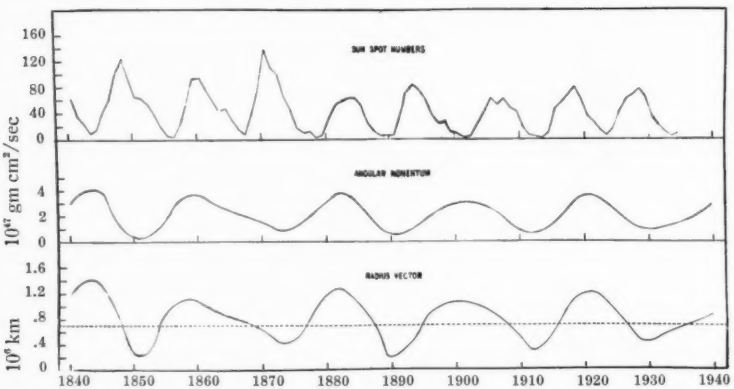


FIGURE 2

Since the sun is moving in a small orbit, the radius of which is equal to or less than the sun's diameter, the outer and inner limbs of the sun will be moving at appreciably different velocities. The maximum difference found in the 1904-1940 interval came in July, 1912. It amounted to 0.043 km/sec.

Purely as a speculation it may be interesting to mention some possible effects if any portion of the orbital momentum were transferred into rotational momentum on the part of the sun. As the sun is fluid, currents would possibly be set up, advancing ahead of the "normal" rotation when the orbital momentum decreases, and falling behind when the orbital momentum increases, in such a manner as to keep the total constant. Such a current would necessarily set up whirlpools as seen in rivers where a current of great strength is flowing between the quieter waters on either side. The reversal of the current would cause a reversal of the direction of rotation of the vortices. The writer has frequently watched such "swirls" and has been wont to compare them with sunspots. A variation in the rotation period of the sun has been suspected for some time.*

The sunspot numbers have been plotted at the top of Fig. 2. Though it has been tempting to suggest the above as a possible source of these disturbances, it is at once evident that the correlation does not exist.

*Transactions I.A.U., 4, 40, 1932.

Stars are My Hobby

By A. D. SHAMEL

Many of us were discouraged during our younger days in our desire to study astronomy because we assumed that a knowledge of mathematics was necessary to its understanding and that a telescope was essential to the appreciation and enjoyment of it. Of course, if one is planning for a professional career in astronomy, mathematical training and telescopic equipment are indispensable. However, the glorious beauties of the stars and a reasonably clear understanding of the inspiring celestial panorama on view every clear night are open to all, even to those who are without mathematical ability or the advantages of a telescope. If this fact could be fully appreciated, it seems to me that many more persons would be encouraged to take advantage of these opportunities to enjoy this grandest of all spectacles than is the case at the present time. It is with the hope that my experience along this line may prove to be slightly helpful that the following personal narrative is offered for the benefit of those who would like to learn how to enjoy the stars but are deterred from doing so by reason of a lack of knowledge of or interest in mathematics and who are without the use of a telescope.

Some twenty-five years ago a neighbor, the late J. C. Deagan, asked me if I had ever seen the crescent of Venus. A negative reply prompted an invitation to observe this interesting phenomenon with the aid of a newly purchased telescope. That experience was a never to be forgotten one, not so much on account of the beautiful crescent of Venus as revealed by the telescope but rather for the reason that my friend began pointing out the constellations then in view together with a description of some of their outstanding characteristics. It was a clear, dark summer evening with Scorpio spread across the southern heavens with its glowing red heart, Antares, finely in view. My attention was also called to the beautiful blue-white star Vega, Alpha Lyrae, which I have continued to esteem as the most beautiful single star in the heavens. The Big Dipper, The Little Dipper, The Dragon, Cassiopiea, Cygnus, the Northern Crown, Hercules, many other constellations, and the Milky Way were pointed out with the aid of a focusing flash light that proved to be a very satisfactory star pointer. All this seemed almost incomprehensible to me at the time but my interest was aroused with a desire to know more about these fascinating stars and star groups. My friend, while realizing my ignorance, was pleased with my enthusiasm and gave me a little outline for study that I have followed since as circumstances have permitted throughout the intervening years. There has been but little expense to me in the pursuit of this hobby, an important consideration to many of us. It has required some little systematic mental effort on my part and some interesting reading at times in periodicals and books that are available at most public libraries. I have been compen-

sated for these slight requirements many times over by a little better understanding of my place in the scheme of things, a new viewpoint of life, many interesting and congenial friends, and a never ending source of entertainment through watching the stars, and a more vital appreciation of the beauty and an intelligent interest in the glorious celestial phenomena. This picture is freely available for observation by all, young or old, without any distinction as to race or creed or condition of servitude. A little better understanding of the stars does much to calm the discontented spirit and solve some of the mental problems of all people whose imagination enables them to grasp even to a slight degree the message of the stars and to those who appreciate a little of their significance.

In the first place I was led by my friend to study rather carefully a few simple objects so as to carry in my mind a rather clear picture of those fundamentals. First the general plan and something of the more striking features of our solar system. This involved developing a mental image of the sun, the planets, their orbits and their satellites, the asteroids, meteors and meteorites, comets, the zodiacal light, and other related phenomena. This was not accomplished all at once nor is this picture complete even now, but the point is I have learned from elementary books and observations the most important known facts about our solar system. Naturally, I learned something of the size of the sun, the known planets, their moons, and their orbits. The next step was to learn a little about the distances of each planet from the sun and from its sister planets. I gradually built up an image of this system that is firmly intrenched in my mind so that I am now able to identify each visible planet as it appears in the heavens and, on seeing it, to recall some of its important characteristics. Nearly everyone can soon learn to do this too, I think. Many very interesting facts are known about the sun and its family of planets and these are simply told in several books available at most libraries. Radio talks by astronomers have helped develop this picture as have several periodicals including POPULAR ASTRONOMY, *Monthly Evening Sky Map,* and the *Scientific American.*

The next step in my star-gazing experience was to learn a little about the galaxy, the island universe of which we are an insignificant part, and something of the location of our solar system in it. First the Milky Way, its makeup and characteristics, then the location and appearance as a faint star of the great star cluster in Hercules, all of the first and some of the second magnitude stars that strike the eye and challenge one's imagination during different seasons of the year. Some of the facts learned about those stars were their distance from our sun, their relative size and brightness, and the constellations with which they are associated. Several trips to the tropics about that stage of my education enabled me to learn the outlines of the constellations and the most striking stars of the southern hemisphere. It was also extremely com-

forting to see my old friends while in distant lands, the visible constellations and the stars of the northern hemisphere.

In all I have learned to know about 21 first and about 50 second magnitude stars and perhaps 40 of the most conspicuous constellations. This may seem to be a rather large effort to some but it must be remembered that this knowledge was gathered over a period of several years.

After the first evenings spent in locating and fixing the appearance of the constellations then in view and their most conspicuous stars, their recognition came rather easily as it will to anyone who earnestly tries to accomplish it. It takes a little time to recognize the constellations and their characteristic stars at different seasons and at different times of the night as they pursue their stately march across the heavens. A little practice will soon enable almost everyone to know at first sight each conspicuous constellation and its brightest stars and the mental effort required to do so will be well repaid many times over as one becomes more and more familiar with our celestial friends.

In learning to recognize at a glance and to know some of the physical facts and the mythology of the constellations, I followed a simple procedure. First I learned to recognize the 12 constellations on the ecliptic that are commonly called the signs of the zodiac. While doing this it was an easy matter to learn to know a little of some of the other interesting constellations that are visible during the various seasons of the year. While doing this I read from time to time two books on the mythology of the stars, "Star Lore of All Ages" by William Tyler Olcott and "Age of Fable" by Thomas Bulfinch. These fascinating, mythological stories are packed full of human interest and lend enchantment to the study of the heavens. Those books are available in most public libraries and both are beautifully illustrated. The illustrations are quite helpful in the development of mental pictures of the ancient conceptions of the constellations.

In identifying the constellations and their principal stars, I have found a sky map to be very useful and have used a flashlight to aid in locating the outline of stars on the map, turning it off after studying the map so as to avoid light interference and then searching the sky for the stars as shown on the map. By repeating this operation as often as necessary it is possible for nearly everyone to locate each constellation in view and to identify the brighter stars in it.

The street lighting now common in many cities renders star-gazing somewhat difficult for some of those living in such communities. However, it is usually possible in the residential districts to find suitable locations where the bright lights can be at least partially screened off from too great interference. There are parks and other pleasant places in most cities where the visibility of the stars is fairly good. As one's interest grows in this study, there is a natural inclination to visit the desert, the mountains, and other country districts where one can enjoy this hobby to the full without interference. This reason for getting out into

the wide open spaces is in itself, in my opinion, a worthwhile by-product of star-gazing.

To the inexperienced ones who would like to study the stars a little for themselves and perhaps discover some answers to questions that have arisen in their minds about them, perhaps the following suggestions from my experience may prove to be somewhat helpful.

If possible, an experienced observer should be sought out and consulted. My experience has been that almost everyone trained in this subject is eager to help interested persons and willing to share generously their time and abilities with those who desire aid. This fine standpoint seems to be inherent in the mental makeup of every astronomer with whom I am acquainted.

A subscription to some periodical that publishes sky maps and timely astronomical notes will be of great help in this quest for a better knowledge of the earth, our moon, our neighboring planets and their satellites, the sun, and the stars in the heavens above. I have found the *Monthly Evening Sky Map* and POPULAR ASTRONOY most helpful, and the articles on astronomy in the *Scientific American* very interesting. If unable to subscribe for one or more of these outstanding monthly publications on this subject they can usually be found for reference in public libraries.

Fortunately there are now available several books on this subject written by outstanding men and women for the purpose of aiding the beginner to understand and acquire a clearer mental picture of the stars and their relationships. Most librarians and bookstore employees will be glad to recommend the ones which will more nearly suit the needs of the particular enquirer. Oftentimes it is possible for the beginner to borrow suitable books on astronomy from older and more experienced star-gazers.

I have listened to lectures by competent astronomers or their interpreters over the radio now and then at weekly intervals during the past ten years. It is usually possible to obtain such programs during one or more seasons of the year from some broadcasting station.

It will help the novice, as it did me, to visualize clearly the make-up of our solar system, to learn to understand the meaning of such terms as light-year, ecliptic, celestial equator, precession of the equinoxes, meteor, meteorite, eclipses of the sun and moon, nebula, star cluster, comet, zodiacal light, phases of the moon and of Venus, and other terms that will be met with rather frequently while reading astronomical publications. These interpretations have to be worked out by one's self, and there is no easy way but the effort is stimulating to one's imagination and to clear thinking.

The colors of the stars include all those of the rainbow and under favorable seeing conditions all of the primary colors can be distinguished by the unaided eye if one learns where to look for them but a small telescope will help in distinguishing the colors. To me this phase of star

gazing, revealing the glorious, glowing, living and everlasting colors of the stars, has been one of my most satisfactory experiences.

Naturally, if one's interest in the stars proves to be a sustained one, as is often the case, the need will eventually be felt for the aid of a telescope. With most high schools and Junior Colleges now equipped with good telescopes, with friendly star-gazers who are fortunate enough to own one, and with astronomical observatories and planetariums located in some places, this natural desire can usually be gratified without the actual purchase of a telescope. In the beginning field glasses will be useful. Then too, for those with a mechanical bent there is always the possibility of building one's own telescope, as thousands of star-gazers are now doing throughout the country at a very low cost.

It may be of some interest to list here the objects that have intrigued me most during my little star studies. They include our earth and moon, Jupiter, Saturn, Mars, Venus, 3 comets, 3 novae, the Great Nebulae of Andromeda and Orion, meteors, particularly those of August and November showers, meteorites, the Milky Way, constellations, particularly the signs of the zodiac, the first magnitude stars, star clusters, especially the one in Hercules, the zodiacal light, eclipses of the sun and moon, some observations of variable stars (Algol and Mira), and the colors of the brighter stars as well as some of the beautiful double stars. Naturally many other interesting astronomical side-lights have come to my attention during these studies that have awakened my interest, but it seems unnecessary to mention them at this time.

The most important point of all, I think, is for one to make a beginning and the gradual development of one's interest will naturally follow depending somewhat upon one's tastes, enthusiasm and capacity for sustained effort along this line. For those who may want to go farther than the average person in this delightful voyage of celestial discovery, means can usually be found which will assist the explorer. In this somewhat hurried age that is so confusing to many of us, the quiet and intelligent contemplation of the stars will almost surely be found to be a great comfort and solace. In no other way can I obtain so much calmness of spirit and true sense of freedom. I think that this feeling is shared by many other star-gazers who have had an experience somewhat similar to mine. I have found this little study to be a favorable opportunity to orient myself a little better with life, my surroundings and with the infinite.

Time by the Stars

By MORGAN CILLEY

A few years ago, one or two articles were published (in POPULAR ASTRONOMY) on "telling time by the stars." The most interesting, perhaps, was that by Father Rigge, who used β Ursae Minoris (Kochab) as his indicator or hour hand, so to speak. The following is a method based on his but which, being simpler, is more easily grasped by the average layman. Father Rigge's method required a considerable amount of mental arithmetic which was somewhat confusing to most of the popular enthusiasts.

Any prominent circumpolar star or stars can be used such as the "pointers" in the "Big Dipper," γ Cassiopeiae (the point in the "w"), or that of Father Rigge's, β Ursae Minoris (Kochab). When the pointers are too low to be seen γ Cassiopeiae can be used and *vice versa*.

The date when the star is on the meridian at midnight is the basis. That, together with the fact that the stars gain 4 minutes a day on the time, due, of course, to the earth's revolution around the sun, is all that has to be memorized. The pointers are on the meridian, or culminate, at midnight on March 8, γ Cassiopeiae on October 5, and β Ursae Minoris on May 6 (upper, or towards the south); β Ursae Minoris is at lower culmination (between the pole and the north point of the horizon) on November 6.

Since the stars advance on the time 4 minutes daily (or 3.9 minutes, to be a lttle more exact) for dates preceding the culmination dates given above, the time will be ahead of the star, while, for dates following, it will be behind the star; an easily remembered item. And the number of minutes that the time precedes or follows the star, will be the number of days, before or after, multiplied by 4.

Example: An observer on November 1 estimates β Ursae Minoris to be $2\frac{1}{2}$ hours before its lower culmination, the stars moving counterclockwise, of course. Since on November 6 the star and the time coincide (and the star can then be used directly to tell the time), on November 1 the time will be ahead of the star by 20 min (4 min $\times$ 5) and the time, then, is but 2 hrs and 10 min (2 hrs 30 min less 20 min) before midnight or 10 minutes to 10:00.

Owing to the difficulty of exactly estimating the hour angle of the star, 4 min per day as a multiplier is near enough. If, however, the observer wishes to figure a little closer on dates a month or more before culmination, all that is necessary will be to multiply the number of days by 4 (as above) then subtract 1/10 the number of days. As, for instance, suppose the same observation was made on December 25 or 49 days after culmination at midnight (November 6) $4 \times 49 = 196$ less 5 (4.9) = 191 min or 3 hrs and 11 min. This is the amount that the time follows the star and, since it was estimated that the star was 2 hrs

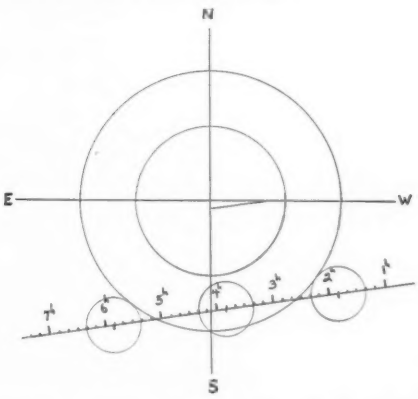
and 30 min before midnight the time will be 3 hrs 11 min plus 2 hrs 30 min before midnight or 19 min past 6:00. But since any estimate made which comes to within 15 or 20 min of the actual time is considered a good one, it will be seen that it is hardly necessary to go to the trouble of multiplying by 3.9 instead of by 4 per day.

This method seems to be interesting not only to boy scouts and high-school students but to others as well. The writer some months ago was overtaken by dark while he was out in the mountains. Having no flash-light he could not see his watch and it was a great satisfaction to him and his fellow hiker to "tell the time by the stars."

Lunar Appulse

By RALPH C. LOWE

On December 28, 1936, there will be a lunar appulse, the only appulse of 1936, which is visible throughout the entire country. The moon enters the penumbra and passes quite close to the edge of the umbra, passing at a distance of less than five minutes of arc.



The accompanying diagram is a graphic representation of the phenomena of the appulse, done according to Rigge's method. The moon's orbit is graduated in Greenwich Civil Time, and the three smallest circles represent the moon at the three phases of the appulse. The large concentric circles represent the umbra and penumbra.

The times of the phases as seen from the diagram are—

	G.C.T.
Appulse begins	$1^h\,51^m$
Middle of Appulse	$3^h\,52^m$
Appulse ends	$5^h\,53^m$

The times of beginning and ending are not observable, due to the

faintness of the penumbra at its edge. The midphase should be seen as a definite darkening of the moon's limb at about eight degrees to the east of the north point of the disc. The moon dips into the penumbra to the extent of 0.87 of its diameter.

At mid-appulse, the moon is 67° above the horizon in azimuth S 45° E, in the vicinity of Philadelphia.

It must be remembered that Greenwich Civil Time is five hours ahead of Eastern Standard Time, and hence the observer in the United States will look for the middle phase of this appulse on Sunday evening, December 27, at $10^h\ 52^m$ Eastern Standard Time.

DELAWARE COUNTY INSTITUTE OF SCIENCE,
MEDIA, PENNSYLVANIA.

Planet Notes for January, 1937

By CLIFFORD E. SMITH

Note: All times, unless otherwise stated, are Central Standard Time.

The *Sun* will be moving with a northeasterly motion from the central part of Sagittarius to the central part of Capricornus. On January 1 at 8:00 A.M. the earth will be at perihelion, that is, the earth will be nearest the sun for the year. At the beginning of the year the earth will be about 91.34 million miles from the sun, and this distance will increase about 190,000 miles during the month. The position of the sun on the first and last days of the month will be, respectively: R.A. $18^h\ 44^m$, Decl. —23° 03′, and R.A. $20^h\ 53^m$, Decl. —17° 33′.

The phenomena of the *Moon* will occur as follows:

Last Quarter	Jan.	4 at	8 A.M.
New Moon		12 "	11 A.M.
First Quarter		19 "	2 P.M.
Full Moon		26 "	11 A.M.
Apogee		6 "	9 A.M.
Perigee		21 "	9 P.M.

Mercury will be in northern Sagittarius. At the beginning of the month it will be an evening object, but, by the end of the month, it will be a morning object again. Inferior conjunction with respect to the sun will occur on January 14 at 4:00 P.M. Conjunction with respect to the moon will occur on January 12 at 8:00 P.M. (Mercury 10′ S). The distance of Mercury from the earth will be about 85 million miles at the beginning and ending of the month, but this distance will be only about 60 million miles during the middle of the month. The apparent diameter of Mercury on January 1 will be about 7.2 seconds of arc. The position of Mercury on January 1 and on January 31 will be, respectively: R.A. $20^h\ 07^m$, Decl. —21° 02′, and R.A. $19^h\ 11^m$, Decl. —20° 25′.

Venus will be an evening object in Aquarius and in western Pisces setting about three hours after the sun. Its distance from the earth will decrease from about 88 to about 68 million miles, and the change in apparent diameter will be from about 17.7 to about 22.9 seconds of arc. Conjunction with the moon will occur on January 16 at 9:00 A.M. (Venus 6°.5 S), and a conjunction with Saturn will occur on January 23 at 8:00 P.M. (Venus 1°.9 N).

Mars will be a morning object in Virgo. Toward the end of the month it will

rise about midnight. Its distance from the earth will decrease from about 155 to about 125 million miles, and its apparent diameter increase from about 5.7 to about 6.9 seconds of arc. Its apparent motion among the stars will be easterly. Conjunction with the moon will occur on January 5 at 10:00 P.M. (Mars 6°.1 N).

Jupiter will be a morning object, and its apparent position will be near that of the sun. At the end of the month Jupiter will rise about two hours before the sun. Its distance from the earth will be about 570 million miles, and its apparent diameter will be 30 seconds of arc. A conjunction with the moon will occur on January 11 at 11:00 A.M. (Jupiter 1°.3 S).

Saturn will be an evening object in eastern Aquarius, and, during the middle of the month, it will set about four hours after the sun. Its distance from the earth will be about 940 million miles, and its apparent diameter will be about 15 seconds of arc. Conjunction with the moon will occur on January 16 at 10:00 P.M. (Saturn 7°.9 S), and a conjunction with Venus will occur on January 23 at 8:00 P.M. (Saturn 1°.9 S). The apparent motion of Saturn among the stars will be easterly.

Uranus will be an evening object in southern Aries. During the middle of the month it will rise about noon local time since quadrature east of the sun will occur on January 25 at 8:00 P.M. The distance of Uranus from the earth will be about 1800 million miles, and its apparent diameter will be about 3.5 seconds of arc. Conjunction with the moon will occur on January 20 at 3:00 A.M. (Uranus 4°.5 S). Its apparent motion among the stars will be westerly until January 14 when it will become easterly. The position of Uranus on January 15 will be R.A. $2^h\ 14^m$, Decl. $+12°\ 58'$.

Neptune will be a night object in southeastern Leo between σ and τ Leonis. During the middle of the month it will rise at 10:00 P.M. local time. Its distance from the earth will be about 2750 million miles, and its apparent diameter will be about 2.5 seconds of arc. Its apparent motion among the stars will be westerly. Conjunction with the moon will occur on January 2 at 1:00 P.M. (Neptune 6°.9 N). A second conjunction with the moon will occur on January 29 at 9:00 P.M. (Neptune 6°.8 N). Its position on January 15 will be R.A. $11^h\ 21^m$, Decl. $+5°\ 25'$.

OCCULTATION PREDICTIONS

(Taken from the *American Ephemeris*)

OCCULTATIONS VISIBLE IN LONGITUDE $+72°\ 30'$, LATITUDE $+42°\ 30'$.

Date 1937		Star	Mag.	IMMERSION Greenwich C.T. (h m)	IMMERSION a (m)	IMMERSION b (m)	IMMERSION Angle E from N (°)	EMERSION Greenwich C.T. (h m)	EMERSION a (m)	EMERSION b (m)	EMERSION Angle E from N (°)
Jan.	2	p^2 Leo	6,2	6 21.4	—1.5	+0.7	104	7 35.8	—1.1	—1.1	322
	3	13 B.Vir	5.8	7 42.7	—1.3	—0.4	128	9 4.8	—1.6	—0.6	300
	4	q Vir	5.4	5 46.5	—0.6	+1.4	95	6 48.6	—0.4	—0.5	323
	6	231 G.Vir	6.4	13 13.0	—2.1	—0.6	91	14 36.8	—1.6	—1.9	306
	15	51 Aqr	5.8	25 52.6	+0.3	+3.1	359	0 20.6	—1.0	—4.1	305
	22	A Tau	4.5	5 15.4	—0.1	—2.5	130	6 1.8	—0.7	—0.1	230
	22	39 Tau	6.0	5 42.6	+0.7	—4.2	155	6 8.0	—1.3	+1.6	206
	24	141 Tau	6.3	1 2.8	—1.9	—2.1	142	1 57.1	—1.9	+2.7	227
	24	14 B.Gem	6.0	5 16.6	—0.9	—1.9	121	6 22.0	—1.0	—1.1	266
	25	ξ Gem	3.7	1 34.6	—1.7	+1.1	85	2 49.6	—1.7	—0.9	300
	29	237 B.Leo	6.3	12 6.3	—0.5	—0.9	67	12 47.3	0.0	—2.6	342
	30	e Leo	5.1	5 51.4	—1.2	—0.8	136	7 11.2	—1.8	—0.5	292

Occultations Visible in Longitude +91° 0′, Latitude +40° 0′.

Jan.	2	p^3 Leo	6.2	6	2.8	—0.6	0.0	127	7	13.6	—1.1	+0.4	291
	3	13 B.Vir	5.8	7	30.5	—0.3	—1.6	161	8	29.4	—1.8	+1.5	262
	6	43 H. Vir	5.6	11	14.3	—2.6	+1.8	74	12	17.3	—0.8	—1.8	340
	6	231 G.Vir	6.4	12	34.7	—2.0	—0.4	115	14	6.7	—2.1	—1.0	294
	6	236 G.Vir	5.7	13	47.6	—2.2	—0.7	106	15	18.9	—1.9	—1.6	295
	22	192 B.Tau	6.2	8	29.2	0.0	—0.8	75	9	18.4	+0.5	—1.3	288
	24	141 Tau	6.3	0	32.2	—1.7	—1.1	138	1	21.4	—1.0	+3.2	222
	24	14 B.Gem	6.0	5	3.4	—1.0	—3.7	153	5	52.6	—2.4	+1.4	231
	25	ζ Gem	3.7	1	7.9	—1.0	+1.4	87	2	18.8	—1.5	+0.2	289
	29	237 B.Leo	6.3	12	12.6	—1.0	—1.2	86	13	9.0	—0.3	—2.4	330
	30	e Leo	5.1	5	41.9	—0.2	—2.5	172	6	30.7	—2.2	+2.2	251

Occultations Visible in Longitude +120° 0′, Latitude +36° 0′.

Jan.	5	75 Vir	5.6	14	24.0	—1.5	—1.7	145	15	48.0	—2.6	—0.8	274
	6	43 H.Vir	5.6	10	38.5	—0.2	—0.1	131	11	46.7	—1.1	+0.7	282
	6	231 G.Vir	6.4	12	16.2	..	..	184	12	48.3	..	..	231
	6	236 G.Vir	5.7	13	6.8	—0.4	—1.7	160	14	11.6	—2.9	+1.1	256
	22	192 B.Tau	6.2	8	29.4	—0.3	—1.9	119	9	23.8	—0.6	—0.4	245
	24	141 Tau	6.3	0	3.2	—0.4	+0.5	114	0	55.5	—0.1	+1.8	241
	24	η Gem	3.3	6	55.4	—2.5	+1.1	63	7	55.2	—1.0	—3.1	325
	25	ζ Gem	3.7	0	50.8	+0.1	+1.6	73	1	45.4	—0.6	+0.3	295
	28	14 Sex	6.3	13	27.4	—0.4	—2.4	150	14	22.2	—0.6	—1.3	267
	29	237 B.Leo	6.3	11	14.7	—1.5	—1.8	134	12	35.0	—1.6	—1.7	295
	29	55 Leo	6.0	13	41.4	—1.5	—0.7	76	14	33.5	—0.3	—2.8	341

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result, in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b;* apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Observations for October: Observations were received from observers during the month of October as shown by the following list:

Name	Vars.	Observations	Name	Vars.	Observations
Adamopoulos	1	1	Campbell	1	14
Ahnert	28	193	Chartier	12	13
Ancarani	10	12	Christman	35	35
Andrews, J.	7	9	Cilley	67	154
Ashbrook	1	3	Diedrich	33	189
Beck	1	1	Ellis	53	121
Blunck	57	125	Ensor	67	140
Bouton	60	91	Fairbanks	15	26
Brocchi	42	137	Focas	78	212
Brown, R.	11	19	Franklin	24	34
Brown, S. C.	21	25	Friton	20	49
Buckstaff	23	88	Halbach	18	23
Callum	36	63	Hamilton	25	62

Name	Vars.	Observations	Name	Vars.	Observations
Hartmann	119	257	McLeod	32	72
Herbig	68	214	Peck	35	194
Hiett	13	34	Peltier	180	233
Hildom, A.	22	52	Perkinson	4	7
Holt	33	49	Recht	1	1
Houghton	71	229	Recinsky	8	33
Houston	87	134	Rosebrugh	29	98
Howarth	7	7	de Roy	9	24
Huruhata	4	12	Schmidt, R.	5	10
Jensen	16	24	Seely	11	26
Jones	117	360	Shultz, Miss	15	15
Kempinski	4	4	Sill	30	60
King	14	17	Simpson	24	50
Kirkpatrick	22	187	Smith, F. P.	33	52
Koons	36	43	Smith, F. W.	9	10
de Kock	38	138	Smith, J. R.	13	14
Lewis	23	33	Starr	39	39
Loreta	76	130	Strelitzer	33	148
Marshall	2	19	Thomas, Mrs.	1	7
Meek	32	105	Thorndike	4	5
Mennella	13	25	Thorne	9	12
Millard	31	99	Treadwell	10	22
Mitchell, R. A.	18	61	Walton	9	44
Monnig	16	50	Watson	16	27
Moore	9	12	Webb	32	45
Morse	7	11			
Murphy	8	31	78		5422

Mr. J. Russell Smith, of Smyer, Texas, contributed for the first time. Mr. Joseph Meek, of Tucson, Arizona, is now observing with the Jewett 5-inch refractor, and Signor Eppe Loreta, at Bologna, Italy, has at his disposal the A.A.V.S.O. 8-inch reflector formerly located at Faenza, Italy.

Twenty-fifth Anniversary Meeting: The twenty-fifth anniversary meeting of the A.A.V.S.O. was held at the Harvard Observatory beginning October 16 and ending October 18. On Friday evening, the Association was the guest of the Bond Astronomical Club and of the Amateur Telescope Makers of Boston. The program of that evening included reports on the summer activities at the Harvard Observatory; dealing first with the Harvard Summer School of Astronomy, second, with the meeting of the American Astronomical Association, held early in September, and last, the Harvard Tercentenary Scientific Symposia, held later in that month. The regular business meeting of the Association was held on Saturday, October 17, at which time reports of officers and committees were submitted and approved. The report of the Recorder showed an increased activity in the use of the Charles Y. McAteer Library; a slightly less active use of the Slide Collection than in past years, although slides were loaned on 59 occasions to the number of nearly 1300. Of the publications of the Association, five numbers of Variable Comments were distributed to members, comprising a supplementary number to Volume II, referring to the work of the late J. H. Skaggs, and four numbers of Volume III, containing accounts of the "Twenty-fourth Annual Spring Meeting at Mount Holyoke College," "The International Astronomical Union in Paris, 1935," "The Fourth Annual Report of the Pickering Memorial Astronomer," and "The A.A.V.S.O. Meeting Held at Harvard Observatory, on October 16, 1935."

In no previous year has such a large amount of literature been sent to persons

inquiring for information regarding the Association. The number of individuals receiving such information totalled 226.

Two numbers of *Harvard Annals* 104, containing two quarterly contributions of variable star observations, have been issued. The third number is in press.

The search for bright novae, under the direction of Mr. L. E. Armfield, of Milwaukee, was given greater impetus due to the discovery of several novae during the year. This work was greatly facilitated by the publication of the A.A.V.S.O. Star Atlas, the work of Mr. D. F. Brocchi.

The report of the Photographic Committee, under the direction of Mr. Lynn H. Matthias, of Milwaukee, indicated that progress is being made, slowly but surely.

The number of charts distributed by the Chart Curator during the past year totalled 6606. Also, 48 copies of the A.A.V.S.O. Star Atlas were distributed.

During the year ending September 30, 1936, 45,000 observations were made. Eugene H. Jones, of Goffstown, New Hampshire, headed the list, followed by Ferdinand Hartmann, of Springfield Gardens, L. I., New York, Leslie C. Peltier, of Delphos, Ohio, and H. E. Houghton, of Cape Town, South Africa. Eight observers were included in the "1000 Class," while sixteen observers contributed between 500 and 1000 observations. One hundred and eighty-seven different observers took part in the observing program. The grand total of twenty-five years of effort on the part of the Association reached 552,790 observations, and in this work Messrs. Olcott, Bouton, Lacchini, and Chandra were observers for practically all the quarter of a century just concluded.

At the afternoon session on Saturday, the Third Merit Award was given, posthumously, to the late Secretary of the Association, William Tyler Olcott. The President of the Amateur Telescope Makers of Boston, assisted by two others proficient in the art of mirror making, gave a very clear demonstration of the grinding of mirrors.

New members elected to the Council were: Messrs. D. F. Brocchi, of Seattle, Washington, Mr. Ferdinand Hartmann, of Springfield Gardens, L. I., New York, and Mr. Leo J. Scanlon, of Pittsburgh, Pennsylvania. Rev. Tilton C. H. Bouton, of St. Petersburg, Florida, was reelected. The following officers were elected for the ensuing year: President, Harlow Shapley; First Vice-President, L. E. Armfield; Second Vice-President, D. F. Brocchi; Secretary, Charles W. Elmer; Treasurer, P. W. Witherell; Recorder, Leon Campbell.

Some interesting papers were presented including those on the observation of red variables, photographically, by Messrs. Watson and Woods, and visually, by Mr. Rosebrugh. Solar studies came in for discussion by Dr. D. H. Menzel and Mr. Kirkpatrick. Novae were discussed by Dr. C. P. Gaposchkin and Miss Harwood.

The Council voted to award the David B. Pickering Nova Gold Medal to Mr. Kazuaki Gomi, of Naganoken, Japan, as the original discoverer of Nova Lacertae. They voted also to establish a memorial at Harvard Observatory to the late William Tyler Olcott, the nature of this memorial to be determined later.

At the evening banquet, Dr. J. C. Boyce, of the Massachusetts Institute of Technology, reported on his experiences in connection with the recent Russian eclipse. Mr. David B. Pickering read Mr. Olcott's account of twenty-five years of A.A.V.S.O. activities.

On Sunday, October 18, a large group of members and their friends journeyed to the Oak Ridge Station of the Harvard Observatory, at Harvard, Massachusetts, to inspect the astronomical equipment there and to enjoy a picnic lunch.

Novae: To the list of novae discovered during 1936 must be added another one, this too, in the constellation of Aquila, discovered, as was Nova Aquilae (191201), by Mr. Nils Tamm, at Bro, Sweden. At the time of discovery, on October 7, the magnitude was reported as 7.0. From photographs studied at Harvard, we now know that the Nova was fainter than magnitude 13.0 on September 17, was at magnitude 11.5 on September 20, and at magnitude 6.6 on September 22. Maximum magnitude seems to have occurred on, or about, September 24, but what this magnitude actually was is still in doubt. Late in October, the Nova appeared to be fluctuating around visual magnitude 8.5.

Nova Sagittarii No. 16: Information recently at hand indicates that the latest nova discovered in Sagittarius was found, visually, by Mr. Sigeki Okabayashi, of Kobe, Japan, on the evening of October 4, at 7:00 o'clock, (J.C.S.T.); this discovery, as announced in Variable Star Notes for November, was later confirmed by observers in South Africa. The Nova soon became too low on the southwestern horizon for observation in northern latitudes.

SS Cygni Type Variables: Maximum No. 287 of SS Cygni, which occurred on September 24 and was of the anomalous type (slow rise and fall, type C3), reached magnitude 8.5. Variations since minimum, have been peculiar. On October 12, the variable began a slow rise, reaching only to magnitude 10.2, before it dropped again to minimum, this maximum resembling the peculiar maximum 270 observed early in 1934.

SS Aurigae, 060547, and U Geminorum, 074922, are now both well placed for observation and these two variables, though faint at minimum, should not be neglected.

November 12, 1936.

Recent Information concerning New Stars

The *Harvard College Observatory Announcement Card* 399, dated November 19, 1936, contains the following official note relating to a discovery by Dr. W. J. Luyten, which has already been announced in the daily papers.

> SUPERNOVA IN N.G.C. 4674.—Dr. W. J. Luyten of the University of Minnesota has reported the discovery of a stellar image superposed on the image of the spiral nebula N.G.C. 4674 ($12^h\ 40^m8$, $-8°\ 6'$ (1900)). The object appears with magnitude between 13.5 and 14.0 on plates A 8267 and A 8272, made with the Bruce refractor at Arequipa on May 9 and May 11, 1907.
>
> Miss Mohr has examined all available plates of suitable exposure time (about 175 in seven series in the interval from 1887 to 1935) and reports that the object is not seen except on the two plates mentioned above. Even on plates made May 22 and May 31, 1907, with exposures sufficient to have shown a nova if as bright as the nebula, no stellar object appears. On no plate is a change in the total brightness of the nebula observed. At maximum the star exceeds the total brightness of the nebula by one magnitude. There was a decrease in brightness of a few tenths of a magnitude between May 9 and May 11.

It also gives current magnitudes of five present-day novae, as follows:

	M	
Nova Aquilae 1936.6	8.0	on November 10
Nova Aquilae 1936.7	9.0	on November 10
Nova Herculis 1934	7.7	on November 10
Nova Lacertae 1936	9.3	on November 10
Nova Sagittarii 1936	7.4	on October 13

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

Among the reports received for October are records of several exceptionally brilliant meteors. The first was a daylight object seen over Lake Michigan at 4:30 P.M., C.S.T., on October 16. We have had several observations of this, and hope eventually to compute heights. More reports would be welcome. A fine fireball was seen from here and nearby points on October 21 at 8:27 P.M. This was perhaps as bright as the quarter moon. Its path was largely or at least partly over Maryland. Several dozen reports have so far been received. A second fireball, not quite so bright, was also seen from here that same night at 10:29. From near Salisbury, North Carolina, at 11:27 on October 21 a fine meteor was observed to the northeast which left a train of ten minutes' duration. The angular drift was carefully observed. On the same night at 14:24 (i.e., 2:24 A.M., C.S.T., on October 22) an observer from the American *S.S. Paulsboro* in the Gulf of Mexico reported a bright meteor which left an eleven-minute train. It is obvious that the night of October 21-22 was a notable one for fireballs.

This date, of course, was just after the presumed maximum of the Orionids. As the exact paths of the fireballs have not yet been computed, however, we cannot yet say whether the objects belonged to the Orionid stream.

Many reports of regular observing periods on the Orionid nights are now at hand. In North Carolina, J. S. Davis, near Thomasville, counted 21 meteors between 13:35 and 13:41 on October 25-26; and in 100 seconds at 4:10 he saw 7 meteors. He observed from a window, and, while other work prevented him from making accurate counts, he saw numerous meteors on both that night and the next.

J. L. Black at Cleveland, Ohio, also observed from a window: on October 19-20 between 12:50 and 16:10, sky $F = 0.7\pm$, he plotted 23 meteors; and on October 20-21 between 13:19 and 16:19, sky $F = 5.0\pm$ but changeable, he plotted 24. Several bright Orionids were seen each night. Many bright Orionids also were reported by P. O. Parker at Cohutta, Georgia, who plotted 42 meteors on October 19-20 between 11:00 and 13:15, with $F = 1.0$, and 27 meteors on October 24-25 between 12:30 and 15:30, with $F = 0.8$. These observations give corrected hourly rates of 18.7 and 11.2, respectively. Other records indicate that the true maximum of the Orionid shower came almost midway between these dates, on October 21-22—the night of the fireballs.

Eppe Loreta, of Bologna, Italy, reports that the Orionids were very numerous. He was able to observe during exactly the same hours (20:30 to 01:25, T.M.U.) on six nights: October 17-18, 18-19, 20-21, 21-22, 22-23, and 24-25. His numbers for these nights, classified as Orionids and Sporadics, were, respectively: 38 Or, 48 S; 53 Or, 36 S; 80 Or, 71 S; 125 Or, 44 S; 100 Or, 50 S; and 61 Or, 45 S. As Loreta leaves out 5 minutes after each 25-minute observing period, he actually observed 250 minutes on each night. His hourly rates for the six nights were: 20.6, 21.3, 36.2, 40.5, 36.0, and 25.4. The maximum fell upon October 21-22, the night when so many fireballs were seen in America. One Orionid left a 6-minute train (of which Loreta sent a fine drawing) and sixteen left trains of durations from 5 to 15 seconds. Clouds prevented Loreta from observing for the Draconids.

Whenever possible, his observing periods are steady and long. We are glad to see a fellow-countryman of the great Schiaparelli making real efforts to revive interest in meteoric astronomy in Italy.

A number of other reports were received from this country. F. Preucil at Joliet, Illinois, observed on October 19-20 with F = 1.0 from 10:55 to 11:56 C.S.T. and counted 27 meteors all of which he classifies as Orionids. Three were bright, and one of magnitude —3 left a 25-second train. John L. Euart of the Skyscrapers, Rhode Island Amateur Astronomical Society, reports that four members observed at Scituate, Rhode Island, on the night of October 18-19. Between 13:30 and 15:00, three observers counted 79, 92, and 83 meteors, respectively; the fourth, observing for 75 minutes only, counted 67. These four hourly rates are 52.7, 61.3, 55.3, and 53.6, the average being 55.7. A fifth member of the party, Mrs. C. H. Smiley, plotted 34 meteors in the same 90 minutes, with Mr. Euart acting as recording assistant. The sky was clear, F = 1.0. Joseph Leerman at Baltimore, Maryland, observed on five nights in succession beginning October 17-18. The first and last nights yielded only three meteors each for about an hour of observing; but on October 18-19, from 14:25 to 15:45, he saw 11; on October 19-20, from 12:05 to 15:00, he saw 46; and on October 20-21, from 11:55 to 13:55, he saw 25. City lights of course lowered his rates. Two meteors were very brilliant.

E. H. Christman of Farmingdale, New York, observed both October 10-11 for possible Draconids and October 19-20 for Orionids. On the first date from 14:40 to 16:30, F = 0.8, he observed and plotted 19 meteors, but saw no trace of the Draconids. On the second date from 10:05 to 11:30, F = 0.9, he plotted 21 meteors. Most of these were sporadic, as the Orionids are most in evidence in the later hours of the night.

On the whole, we may conclude that the Orionids furnished in 1936 a much better shower than usual, one also notable for some very bright meteors. Certainly several splendid fireballs appeared coincidentally, even if they may not have belonged to the stream. This October display, indeed, seems to have surpassed that furnished by the Perseids last August—an unusual and surprising fact. Undoubtedly radiants can be deduced from the submitted plots which should give further information on the controversial subject of the motion of the famous Orionid stream.

Another good set of observations on the Draconid dates was made by David Hunter of Eugene, Oregon. On October 8-9 between 10:30 and 12:30, F = 0.8, he plotted 9 meteors. Only one came from the general direction of the Draconid radiant, and it may have been a sporadic. This report confirms that of E. H. Christman in showing that the Draconid shower was not in activity on these dates.

I myself observed on November 16-17 for Leonids from 13:50 to 15:30, average F = 0.7 but part of the time fully F = 1.0. In all 12 meteors were seen: 4 certain and 2 probable Leonids were among them, 2 leaving good trains. The date was after the presumed maximum, but evidently Leonids had fallen to a low hourly rate. It is too early for other reports to have arrived.

That interest in telescopic meteors is beginning to be more widespread is evidenced by reports coming in from various quarters. Two that have just arrived are (1) from H. Inouye of Nagoya, Japan, recording 25 observed 1936 August 11 to October 13 inclusive, and (2) from E. H. Jones of Goffstown, New Hampshire, recording 28 observed from 1935 December 18 to 1936 November 12.

Flower Observatory of the University of Pennsylvania,
Upper Darby, Pennsylvania, 1936 November 19.

The 1867 Leonid Meteors

By N. R. LEONARD

Professor N. R. Leonard was in charge of the Department of Mathematics at the University of Iowa from 1860 to 1887. The following paper was presented by him primarily for publication in the Iowa City *Republican*. It was placed in my hands by his son, L. O. Leonard, now Historian of the Rock Island Railroad. I have omitted the names of the observers and a few additional items which appeared of popular rather than scientific interest.

These observations were made before the days of standard time, so Iowa City time was used. It was then furnished by Theodore S. Parvin, whose instrument was set up in Longitude 91° 30′ 10″ and Latitude 41° 36′ 53″.

Professor Leonard observed the 1867 Leonid meteors from the top room of the Old Capitol of Iowa.

C. C. WYLIE.

University of Iowa, November 20, 1936.

Inasmuch as many readers were so unfortunate as not to be witnesses of the great Meteoric Shower of the night of November 13-14, and as many who did see it will be interested no doubt to know what observations were made, I will set forth briefly the facts in the case.

Some weeks ago in anticipation of the event, a company of thirty or forty students was formed having for their object the noting of the *Number, Direction, Period of Visibility,* and *Length of Arc* that might be described by the most brilliant meteors, together with other such items as they might have time or opportunity to notice.

After spending a few evenings in tracing out the constellations, the lookout was commenced on Saturday, November 9, with a view of obtaining practice, and of ascertaining whether there was any gradual increase in the number of falling stars extending over a period of several days previous to the shower. As a result we have not found, save on the mornings of Saturday and Tuesday any more than on any ordinary night in the presence of the full moon.

From the commencement of the watching until the evening of the 13th, only four observers were out at a time, or one for each point of the compass. On that evening they all assembled at my recitation room and were divided into three sections, consisting of twelve each, and assigned respectively to watches from 10:00-12:00; 12:00-2:00; and 2:00-4:00.

The position chosen was the octagonal room in the second story of the cupola of the University Hall, which is the Old Capitol of the State of Iowa, where you may notice that there is a window at the middle of each side, with an exterior column on either side of it, so that when the blinds and sash were removed, an observer, placed within, could view just one-eighth of the sky.

At a few minutes before 10:00 the first section took their places, one at each window, two in a reclining position on the projection outside to keep watch near the zenith, one within at a desk with lantern and paper, previously ruled in columns for the purpose, to keep a record of the observations; and the twelfth to act as occasion might require. The columns were headed thus:

Quarter of Compass; Direction of Motion; Leonid or Sporadic; Time Visible; Arc of Motion; Remarks.

A short time before 12:00 the second section was called up so as to take its place promptly at the expiration of the hour. At 1:20 it was found that one per-

son could not record fast enough, and the unemployed man undertook the record for one-half of the circuit.

The second section was relieved punctually at 2:00. At 2:15 both recorders were unable to keep a full record, and from this time forward each observer counted to himself the number appearing in his portion of the sky, and only called out the most remarkable for record. Sometime before 3:00, one additional observer was placed, first at the southeast window, and second at the east window, so that two observers were counting at each of those windows.

The following table gives the results. Meteors conforming to a direction from the constellationn Leo are listed as Leonids, others as Sporadic.

Hours	Leonid	Sporadic	Total	Remarks
10-11	2	5	7	Prospect poor, a little hazy, with light clouds.
11-12	6	6	12	Squad inclined to doubt whether there would be a shower. Clear.
12-1	35	16	51	Better—Quite Clear.
1-2	102	17	119	Better still—Quite Clear.
2-4	nearly all		5000	Actually counted 4748. Not counted on W. quarter.

Note here the great increase in the proportion of Leonids. Out of 1688 recorded by three observers only 23 were thought to be sporadic. The following table gives the record in each of the eight directions the observers were watching.

Hour	N	NE	E	SE	S	SW	W	NW	Total
10-11	0	2	3	2	0	0	0	0	7
11-12	1	1	1	3	0	5	1	0	12
12-1	6	15	5	5	4	10	3	6	56
1-2	25	85	20	16	3	6	4	6	115
2-3				150		No count			
3-4	693	685	721	1100	507	336	158	448	4748
	727	687	750	1276	514	357	166	560	4987

In the west no count was kept save of the brightest until 3:20 to 3:40. Hence that count is low.

Record was kept of 155 of the most luminous trains, with this result:

Green	49	Very green	9	Total	58
Red	35	Very red	14	Total	49
White	24			Total	24
Train and Meteor of different color				Total	24
					155

In regard to the color, it is my impression that the proportion given by the above figures is not true, save for the brightest meteors, for of the hundreds that left trains behind them the greater number seemed to be of a green color, very many yellow at the middle and gradually changing to green at the margin, a color a little darker than the flame of the metal barium and not far from the hue of copperas. On comparing this statement with the views of several observers, I find all agreeing therein.

The time of maximum was from 3:10 to 3:40. The observers at the southeast window counted by hundreds, keeping the time of each hundred, commencing at 2:52½. The following table shows the time required to reach each hundred, from the first to the eleventh inclusive.

Number	Time for 100	Number	Time for 100	Number	Time for 100
1	7 minutes	5	3 minutes	9	2½ minutes
2	5 "	6	3 "	10	4 "
3	6 "	7	2 "	11	10 "
4	3 "	8	2 "		

The counting of the last hundred was ended at 3:47½. It will be seen by adding the times of the various hundreds that they lost 7½ minutes during their counting. Most of this probably occurred between the fourth and tenth hundreds when in consequence of the great number that appeared, they were unable to keep a reliable count. From this, it would seem that the true time of maximum was between 3:25 and 3:30; and that the decrease was far more rapid after the maximum than the increase had been before.

During the hour from 3:00 to 4:00 and also after 4:00 parties of nine each were formed on the college campus, for the purpose of counting those that issued from Leo. They counted on an average about forty per minute during the time from 3:15 to 3:40.

There was a very fine opportunity to determine the position of the *Radiant,* or point from which they seemed to proceed. According to observations made at 3:15, this radiant was a very well-defined point, close to the star 97 in the sickle of the constellation Leo. At about 3:30 the radiant seemed to be a short line or at most a very narrow ellipse, having this star for its center, and extending a short distance in either way in the direction of the star Zeta.

There were several particular observations taken. The first to be mentioned is, that in some instances a separation took place between the meteor and its train, before the former disappeared.

At 2:51 a meteor started from the radiant and proceeded directly over the star Dubhe, Alpha Ursae Majoris, followed by a broad train about five degrees long. The separation of the meteor and train took place just as the former crossed the star named. The train remained visible for the space of four minutes, drifting meanwhile to the southeast shortening up as it went without growing much, if any, narrower, and disappeared after retreating about seven degrees. The last glimpse that I had of it gave me the idea of a spiral form, but I could not be very positive about it.

At 2:56 another meteor left the radiant and proceeded to the star Zeta Draconis leaving there a train, behaving just as the last described, retreating two degrees in three minutes. At 3:03 another passed over Mizar, Gamma Ursae Majoris, leaving there a train that retreated one and one-half degrees in two minutes.

At 3:08 a very large meteor passed over the head of Orion, leaving there a train eleven degrees long. The meteor was seen to separate into several parts and disappear. The train floated a little to the east of south, a distance of eleven degrees, the middle moving more rapidly than the extremities, so that it took up the form of a crescent with the horns pointing northwest. It should be noted that this train appeared near to the full moon, so that its period of visibility was thereby much shortened. From this train before the separation one observer thought he saw three small black streaks descending for a short distance, and curved backward toward the bottom.

At 4:01 another meteor passed toward Sirius, leaving midway from Leo a train that exhibited the same movements as the last, showing the crescent shape before disappearance.

A change of course in the path of a meteor was definitely noted in one instance. A little after 3:30 a deep red meteor was seen passing very rapidly through Leo Minor, toward the northwest, describing an arc of length fifteen degrees in one-fourth of a second. About midway of its course, it turned abruptly toward the west, the path making an angle of fifteen or twenty degrees with its previous direction.

Several bright meteors were seen to flash out, remain stationary or nearly so

for an instant, and then disappear. As a rule, it may be stated that the nearer the meteors were to the radiant point, the less was their motion.

From the position of the radiant it appears that the inclination of the meteoric stream to the orbit of the earth is twenty-two degrees. From the known motion of the earth, the breadth of the stream crossed from 2:15 to 4:15 was not far from 40,000 miles, and the breadth of the denser part crossed from 3:15 to 3:40 was about 7,000 miles.

In consequence of the presence of the full moon, and the impossibility of counting all the meteors that appeared, the number obtained represents only a small part of the total. It is our opinion that twenty times that number would have been visible had the night been perfectly clear and the moon absent.

University of Iowa, November 20, 1867.

Contributions from the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD, President, *and* H. H. NININGER, Secretary

The Phulmari, Hyderabad, India, Aërolite

By MOHD. A. R. KHAN,
Principal, Osmania University College, Hyderabad, Deccan, India

The Phulmari, Hyderabad, India, aërolite was reported to have fallen some years ago in the district of Auranabad, Hyderabad State, on a farm by the side of the road that goes from the city of Aurangabad to Ajanta of prehistoric-caves fame, between the villages of Chawka and Phulmari, some 20 miles from Aurangabad city. Phulmari being better known than Chawka, I have designated the meteorite by the former name. Detailed information concerning the circumstances of its fall, as reported by trustworthy eyewitnesses, is still awaited, as the man who brought the meteorite to Maulvi Abdul Hag Saheb (the Honorary Secretary of the Association for the Advancement of Urdu) is absent from the station at present.

I received the meteorite from the Maulvi Saheb on August 30, 1936, and had it photographed on the 31st. It weighs, in air, 4064.0 grams, and, in water, at room temperature, 2903.8 grams, having thus a specific gravity of 3.50. Had the air inclosed in its long cracks been completely expelled, the specific gravity would of course have come out slightly higher.

The aërolite may be roughly described as bounded by five faces. Face No. 1 is very concave, with two rather deep, broad channels meeting from opposite sides, the greatest depression being about 0.7 inch deep. This face has a rather long deep pit near one corner, of length 0.8 inch and maximum depth, 0.3 inch. At some distance from another corner, a crack begins from one side of the face; this crack is seen clearly in the photograph. Face No. 2 has lost some portions of the crust in three places near one edge. A long crack runs through the stone to within 1.4 inches from the opposite point, where is it deflected to the adjacent side. There is a short deep channel near the pointed end of the face, and there is a large area where a rather big slice was evidently broken off by impact with the ground. Face No. 3 is roughly triangular in shape, the sharp apex representing perhaps the direction in which the meteorite darted through the air. This face has two hollow pits in it. Face No. 4 somewhat resembles a trapezium. It has two

prominent pits near two of its adjacent sides. Face No. 5 has a somewhat long pit and is the smallest of all the five faces.

The accompanying photograph shows faces Nos. 1 and 3 very clearly. The meteorite was photographed standing on its smallest face (No. 5). Face No. 1 is facing the observer and No. 3 is shown at the top. Face No. 2 is exhibited on the right-hand side of the observer and No. 4 is on his left-hand side.

THE PHULMARI AEROLITE
(approximate maximum dimensions, 8×6×5½ inches)

The entire surface of the meteorite is covered with "thumb-marks"—shallow pits which resulted from the removal of more fusible matter during surfacal incandescence. In places, lines of flow of this molten material, which were produced during the aërial flight of the meteorite, are seen somewhat clearly. Both in the crust and underneath it, are observed distinctly fine spherules of nickel-iron, profusely interspersed with rocky material. The color of the crust is generally dark gray, but is deep black in many places—disclosing a thicker crust and perhaps evidence of second fusion. An unusual thing about this meteorite is the compactness of its material beneath the crust. Attempts to remove, with a knife, one or two

of the larger spherules of nickel-iron (about 0.04 inch in diameter), imbedded in the body of the aërolite and exposed to view on the broken surface, completely failed. The material of the interior is also dark in color and is mottled as a result of its different mineral constituents.

A fragment weighing about 8.4 grams was cut off by rubbing with copper wire and emery powder. A small quantity of this piece was reduced to powder, which, on testing with a bar-magnet, proved to be strongly magnetic. The powder was to some extent soluble in hydrochloric acid and gave off, on heating with this acid, a gas smelling strongly of sulphuretted hydrogen, thus indicating the presence of iron sulphide, presumably in the form of troilite. This solution was made alkaline with *excess* of ammonia and filtered. The filtrate, on treatment with a solution of dimethylglyoxime, gave a rich red precipitate, thus proving the presence of nickel.

Begumpet, Deccan, N.S.R., India, September 3, 1936.

Two Meteoritic Falls in or about the City of Hyderabad, Deccan, India, as Reported by Eyewitnesses*

By Mohd. A. R. Khan,
President, Hyderabad Science Association

1. The Fall near Bood Ali Shah's City "Window" (or Smaller Entrance through the City Wall).

Mr. Saifullah Siddiqui, now Superintendent, Office of the Revenue Commissioner, Gulbargha Division, a gentleman of much learning and culture, enjoying a good position in society, in his Urdu letter dated March 11, 1935, writes to me to the following purport:

"The event happened when I was a young boy (about the summer of 1898, well remembered as the year of a nearly total eclipse of the sun at Hyderabad). It was past dusk and lighting time; my mother and I were reclining in the courtyard, it being too hot inside the house, when all of a sudden an intense light of a reddish color dazzled our eyes. I ran out of the house in great haste. My mother also was much perturbed, as she had never seen such a thing before. Several other people had come out of their houses in fear. Passers-by stopped on their way bewildered, and a hue and cry was raised on all sides that 'A star has fallen, a star has fallen!' When I came out of the house, I saw at a distance of about a furlong, a column of peculiarly intense light extending from the ground to the sky. People rushed to the spot to see what it was. The meteorite had fallen beyond Bood Ali Shah's 'wicket,' which was a little less than a furlong from our house. By the time we reached the spot, the light had disappeared. It was reserved for the happy-go-lucky revellers of the neighboring tavern or public house to witness the phenomenon in its full splendor at close quarters. But I remember perfectly well the spot where the meteorite fell. At some distance in front of the public house, a little towards the right, was located, on somewhat rising ground, the house of Hafiz Saheb, who was also the imam of the mosque attached to the graveyard. By the side of the house was an old tamarind tree and it was quite close to this tree that the meteorite fell.

"When I reached the spot, I did not see the meteorite 'burning' or in a state of luminosity, but I found strewn on the ground several of its pieces that presented the appearance of burnt fireworks. A number of people gathered around

*Read at the Fourth Annual Meeting of the Society, University of California at Los Angeles, June 23 and 24, 1936.

the spot, none of whom, however, evinced much interest in the nature of the phenomenon, beyond regarding it merely as an extraordinary event. Some of them discussed the approach of doomsday, of which they regarded this incident as a precursor, and dispersed! A few of the spectators had in all probability got hold of some of the broken pieces of the meteorite. Ramannah, the owner of the public house, was then alive, but has since passed over to the other world. Perhaps Mr. Babar Ali's people also are aware of this incident. Possibly Maulvi Rahmatullah would be able to throw some further light on the matter; but unfortunately our Maulvis [old-type oriental scholars] are not blessed with an inquiring mind for such mundane matters. If Bhagawan Din is alive, he may be able to furnish additional details. My younger brother, Mr. Amrullah Siddiqui, Barrister-at-Law [of Lincoln's Inn], knows all these people personally. There may be some more persons who are aware of this fact through report or actual observation.

"It appears that the meteorite continued to glow for about half a minute or so after it fell and several people erroneously surmised from its light that some object had caught fire—a by no means rare occurrence in our hot summers."

On March 19, 1935, the writer of this paper went with Mr. Amrulla Siddiqui to the place described in the preceding account and interviewed, first, Maulvi Rahmatullah, one of the few survivors of the old residents living at present in that locality; but he remembered nothing of the incident. The new owner of the public house was then interviewed. He remembered having heard from his neighbors (when he came over to live in that locality) that a "shooting star" had, once upon a time, fallen not far from his shop, and pointed out the approximate place of its fall.

On October 13, 1935, I went to the place again, this time taking Mr. Saifullah Siddiqui himself. He at once identified the spot where he remembered the meteorite to have fallen. The place shown by the present owner of the public house agrees well with it. The tamarind tree that had stood nearby has since been cut down. Mr. Saifullah then inquired after a number of his old acquaintances in that locality and eventually succeeded in finding one Mr. Syed Mohayyad Din, who was an eyewitness of this event and confirmed the account related. He is of about the same age as Mr. Saifullah and confessed that he had not had enough curiosity at the time to carry away as souvenirs any of the pieces from the débris of the aërolite. I call it an aërolite, because it is described as having gone to pieces after it had fallen onto the ground and as having appeared like burnt fireworks.

If Mr. Saifullah, to whose retentive memory I owe this account, had been of riper age at the time of the fall, or had I known him much earlier, while the matter was quite fresh in his mind, it might have been possible to obtain more detailed information, and perhaps to secure some pieces of the aërolite from such people as had got hold of them. The ground where the aërolite fell has been scooped out, levelled and re-levelled these many years, both by natural and by human agencies; so there is no hope of finding any trace of the meteorite at present. Judging from the account related, I would say that it does not appear, moreover, to have been of large mass. A liberal reward, however, has been announced to persuade such of the older residents as may happen to have preserved a piece or two from the débris as souvenirs to part with them. It is feared that a primitive dread arising from an ignorant belief prevailing amongst the superstitious, that meteorites are, if not actually diabolical in their origin, associated somehow with Satan or the devil, must have soon chilled the enthusiasm of the relic hunter and helped the material to become lost.

This aërolite fell in a suburb of a densely populated city, but luckily did no

harm either to life or to property. The public house (rebuilt), referred to in the foregoing account, stands behind a hut. Actually, there is a road between the two buildings, that leads to the city "window."

2. The Fall at a Place Located between Alwal and Boenpalli.

This location is some ten miles to the north of the city of Hyderabad, as described by Mr. Gulam Qader, First Assistant, Government City High School, Hyderabad, in his letter (copied below) to the present writer:

"What Mr. Ghousuddin told you about my having seen a shooting star [fall to the ground] is correct. When I was about twelve years old [about 1901], my people were staying at Ghalib Jung's garden at Alwal and I was going daily to Boenpalli to the Pesh-Imam of the Mosque to get consecrated water for my sister, who was suffering from chronic fever. One day when I was going to Boenpalli as usual, just before dawn, I saw a shooting star descending just over my head and I got frightened. It seemed to travel in a southwesterly direction, making a zigzag curve. As a matter of fact, it fell at a distance of about 200 yards in front of me. Out of curiosity I went to the spot and stood at a distance, and saw the grass burning where the [shooting] star had fallen. I then went away on my business and returned after about two hours. I again went to the spot and found a big piece, of the size of a tennis ball, perhaps a little bigger, more than half of which was buried in the ground. With some difficulty I turned it over with a thick piece of stick, and when I was sure that it was not hot, I picked it up. It was heavy and appeared to me like a piece of pig iron. Its surface was rough and it had become pressed on the side that was buried in the earth. I wanted to carry it home, but as it was a heavy thing, and I did not know the value of it, I threw it into a well which was at some distance from the footpath along which I was walking. One small piece which had fallen [meaning evidently *broken off*] from the mass, I carried home, and related the whole thing to my mother who got frightened and chastised me for my boldness and said that it was Satan who had been beaten down by the angels while trying to go up to the seat of God [Arsh]. Some years later, Mr. A. Viduraj, my science teacher, whom I told about the [shooting] star, expressed his regret that I had not retained the whole mass. The small piece which I had carried home was with me for some time but it was lost later. This took place about 30 years ago. Here I may say that at the suggestion of Mr. Viduraj, I once went to the spot in order to see whether I could reclaim it [the meteorite] from the well. In spite of my search, I could not find the well, but I could locate the vicinity of the incident."

[Signed] GULAM QADER,
Narayanguda, Hyderabad, Deccan, June 14, 1934.

At the request of the writer of this paper, Mr. Gulam Qader went again in search of the memorable spot, but with no better success, a number of houses having been built there in the meanwhile.

Begumpet, Deccan, N.S.R., India.

EDITORIAL NOTE.—The preceding narratives contributed by Professor Khan are interesting. The incorporation of such accounts into the literature of meteoritics is justified, not from the standpoint of authenticated meteoritic falls, but rather as typical records of the manner in which human beings react to events of this kind. Quite likely meteorites fell to the earth in both instances; however, it is doubtful whether either of the objects mentioned was really the object sought. Every year we encounter similar reports which cannot be verified. Both of the foregoing accounts are more consistent with what we know of falls as seen from

great distances than with the experiences of observers who have witnessed falls near at hand. Persons who are close to the place of fall see the light phenomena usually only high in the sky—not near the ground—and the meteorites arrive some moments after the meteor has vanished. Any reference to the terrifying detonations ordinarily heard by persons near to the place of fall is conspicuously absent from the preceding accounts. Credit is due Professor Khan, however, for his persistent efforts to gather and to present the true accounts of these two events.—H. H. N.

Editorial Notice concerning the "Bibliography of Meteoritics"

On account of lack of space in these CONTRIBUTIONS, publication of the "Bibliography of Meteoritics," compiled by Frederick C. Leonard and Robert W. Webb, has, at least temporarily, been discontinued. The last instalment of this bibliography appeared in the *C.S.R.M., P. A.*, **44**, 47-9, January, 1936.—F.C.L.

Secretary's Office: Nininger Laboratory, 1955 Fairfax Street, Denver, Colorado.
Editorial Office: Department of Astronomy, University of California at Los Angeles.

The Meteorite Fall in Oklahoma

On the evening of 1936 August 17, at about 7:07 P.M., C.S.T., a fireball moved through the sunlit sky across central Oklahoma. It was very well viewed in most of Oklahoma and was also seen from points in Kansas and Texas, and as far south as Waco and Tyler, Texas. A field survey of the fireball was made immediately by Robert Brown of the Texas Observers at Ft. Worth, Texas, and in addition to securing observations which will be of considerable value in working out the fireball path, Brown was successful in locating the region of probable fall of meteorites, and in retrieving one meteorite from the fall four days later. Two subsequent visits to the region of the endpoint have been made by Brown, resulting in fuller information and in the recovery of one other meteorite from the same fall, at a point about one mile from where the first one was found.

Strictly tentative results indicate that the fireball first became conspicuous over the region of Tecumseh, Pottawatomie County, Oklahoma, perhaps a few miles south thereof, at a height of about 26 miles. A few of the better observations seem to refer to an earlier portion of the path. The fireball traveled roughly northwest in azimuth at a low slope (about 11°), and underwent several (perhaps three distinct) explosive flares. Detonations were heard in a region along much of the primarily observed path, in a strip at places almost 100 miles wide. A terminal explosion cloud was formed by the final flare at a height of about 13 miles just northwest of Guthrie, Logan County, and persisted with little drift for 15 minutes or more.

The meteorites were recovered beyond the terminal cloud, not far from the town of Crescent, for which they will probably be named. The first one was picked up on the third day after the fall, in a fresh condition, by a boy of about 9 named Eddie Gene Johnson, who was rabbit hunting. Brown was able to locate and examine the hole this meteorite made on striking, and to check the conditions of its fall. Another party had cut fragments off one end of this stone; 1.6 grams of these tiny bits were picked up where they had been allowed to fall when cut off, and the major piece as received by us weighed 72.7 grams, and was loaf-shaped. The second meteorite was found almost seven weeks after the fall and had gone through rains. Its crust showed a considerably different appearance, being discolored brown by spattered sand and rusting; and cracking of the stone itself had also

set in, due to the deteriorating effects of weathering. It weighs only 5.7 grams, and was picked up personally by Mr. Sterling Bunch of the Texas Observers, who accompanied Brown on the third trip of investigation. It is rarely that a meteorite hunter has the privilege of picking up his own meteorite!—but the case demonstrates what large factors interest and knowledge are in the finding of these objects.

The stones themselves are a rather unusual type of meteorites, possibly of the kind classified as carbonaceous chondrites. They have a low density, not far from 2.0 (less than the density of average terrestrial rocks); the interior ground is generally a dull black, with a few scattered white and gray specks, and some glassy-looking yellowish particles; free metal is relatively sparse, but is well shown by the stone which lay out in several rains, and was detected in the other one by X-ray photographs. The crust of the fresh stone is a shiny black and mostly very thin. The material is inclined to crumble and cannot be handled freely without some loss.

A fuller description of the fireball is being worked up on behalf of the American Meteor Society, a number of reports having been obtained by letters in addition to those procured through the field surveys. Later detailed articles will deal with the final fireball data and with proper descriptions and photographs of the meteorites. Further field work is being done to determine more extensive facts about the fall.

Oscar E. Monnig and Robert Brown.

312 West Leuda Street, Ft. Worth, Texas, 1936 November 20.

A Strange Phenomenon, evidently a Daylight Meteor

While duck hunting on Lake Butte des Mortes, a few miles northwest of Oshkosh, Wisconsin, my two companions, Arthur Nelson of Oshkosh, and F. E. Winans of Wauwatosa, and I were witnesses to a strange phenomenon, which occurred sometime between the hours of eight and ten in the morning, on October 29, 1936.

The point at which we were situated was on the south shore of the lake. We were facing the north watching a large raft of duck, when from the east, seemingly low over the water, came a rocket black formation throwing sparks of various colors, which shot across our front and seemed to disintegrate in the northwest. Had any of us been alone we would have thought we were seeing things, but all three of us witnessed the incident.

Both Mr. Arthur Nelson who lives at Oshkosh, Wisconsin, and Mr. F. E. Winans, 1868 N. 70th Street, Wauwatosa, Wisconsin, will verify this report.

F. W. Keppler.

109½ Main Street, Watertown, Wisconsin.

A Brilliant Meteor

On Sunday morning, October 18, 1936, some time between two and four o'clock, my room was suddenly and brilliantly illuminated. Thinking it was due to lightning, I turned and looked out of the east window. I saw what must have been a meteor. It was a flaming object and appeared to be about three inches long and about two wide. It was not falling. I knew it was not an airplane. Its course was slower and steadier than would have been that of an airplane. As far as I can describe it, I saw it going across the sky from the northwest to the southeast and downward. After its disappearance, I heard a distinct, clear and forceful hissing "zing."

Shortly afterward, I saw two smaller burning bodies almost together and

travelling in the same course as did the first meteor. These too were followed after their disappearance by two sounds of the same type, but of less volume and duration. These two reports followed one after the other.

I am eager to know whether these objects were seen by anyone else.

LILLIAN M. MURPHY.

610 S. Coronado Street, Los Angeles, California.

Orionids

On the night of the nineteenth of October a remarkable shower was observed at Vassar College between the hours of 12:00 and 4:20. Florence Flanders and Barbara Peck observed the north polar region and Katherine Gordon and the

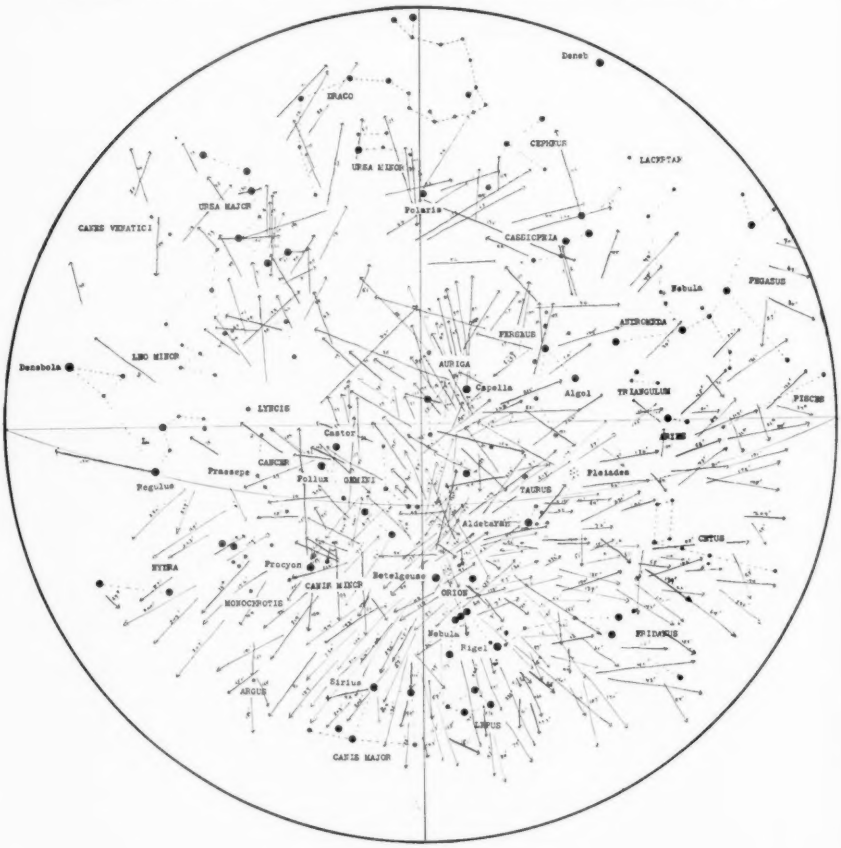


FIGURE 1

ORIONID SHOWER OBSERVED AT VASSAR COLLEGE OBSERVATORY (LATITUDE +40°) ON THE NIGHT OF OCTOBER 19-20, 1936.

author observed the southern region. From the record, three hundred and seventy-four paths were plotted (Figure 1) and the time of each determined to the nearest second. The numbers marked with the prime indicate those observed in the southern region.

As was to be expected, the most pronounced radiant was found in Orion. Observations made on three successive nights by the same observers assisted by Kathleen Allen showed the radiant to change position as follows:

Date	Number seen	Radiant α	Radiant δ	Observers
October 19-20	374	88°5	+15°1	F.F. B.P. K.G. H.W.
October 21-22	78	86.5	14.8	K.A. K.G. H.W.
October 22-23	45	84.7	14.5	H.W.

The radiant point was found by plotting the paths on a celestial globe. Many of the meteors lay outside this central point and seemed to come from a radiant in Auriga to the north of Orion.

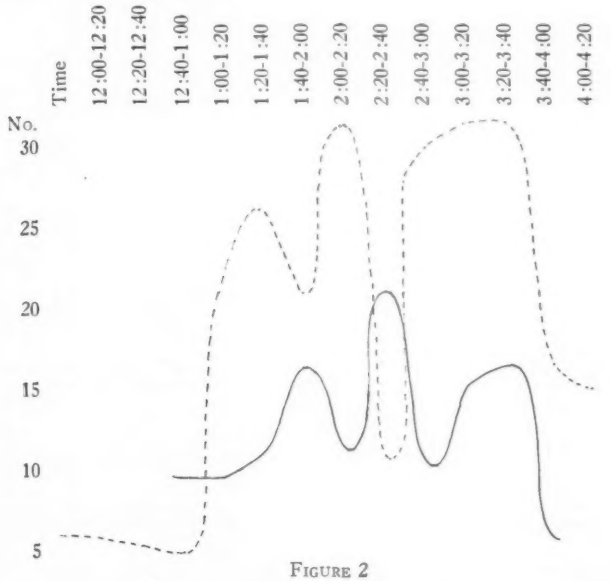


FIGURE 2

It was interesting to note that the meteors came in swarms. Often a great many were seen in a short interval of time and then there would be a lull, and, for a period of four minutes or more, none were visible. These gaps came at intervals of twenty minutes. The maxima and minima are clearly seen in the accompanying graph (Figure 2) which shows the numbers of meteors observed every twenty minutes. There is a wide variation in frequency but the maxima and minima in the regions (a) around the pole and (b) near Orion appear to have very similar curves. Note how the maxima in the southern region, represented by the dashed curve, occur twenty minutes before those in the polar region, represented by the continuous curve.

Figure 3 shows a more detailed record of the frequency of the appearance of

12:00
12:10
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3:30
3:30
3:40
3:50
4:00
4:10
4:20
4:30

FIGURE 3

the meteors observed in the southern region near Orion. The maximum number observed per minute was four, which establishes the vertical scale of the chart.

The color of the meteors varied from yellow to blue. The majority, however, seemed to be yellow. Most of the observed meteors were faint, had short paths, and were very swift. A few were extremely brilliant and moved slowly across the field. One of the brightest occurred on October 19-20 at 3:23. It appeared as a large ball near Polaris in the constellation of Ursa Minor. It had a long path and moved swiftly across the field.

M. HELEN WRIGHT.

Vassar College Observatory.

Comet Notes

By G. VAN BIESBROECK

COMET 1936 *c* (JACKSON-NEUJMIN). This faint comet was found independently by Neujmin at Simeis (Crimea) on September 21, one day later than the original discovery on September 20, hence the double name attached to this object. No observations after the middle of October have been published. It seems that the visibility will cover hardly a month unless the better situated southern observers succeed in following the comet longer. However, the rapid decrease in brightness makes this improbable.

The comets that were followed earlier in the year have now all become too faint. COMET 1936 *b* (KAHO) when last recorded here on October 24 was so faint and diffuse that further measures are hardly to be expected.

The search for periodic COMET D'ARREST should still be continued (see eph., p. 495). The brightness should increase but the region can be reached only for a short time after sunset.

The computing section of the British Astronomical Association gives a search ephemeris for another periodic comet. It is COMET 1858 III (TUTTLE) an inconspicuous object found at Cambridge (U.S.A.) on May 2 of that year. It was followed for 30 days only, but Schulhof established the fact that the period was somewhere between 5.8 and 7.5 years. The object was not seen again until 1907 when Giacobini at Nice (France) found on June 1 an unexpected object 1907 III, whose orbit proved to correspond to that of COMET 1858 III. Assuming that in that interval ten revolutions had taken place, the British computers have determined the perturbations for the whole period. Large perturbations by Jupiter in the revolution 1902 to 1907 made the computations difficult and hence the following ephemeris (*Journal Brit. Astr. Assoc.*, Feb. 2, 1936) is uncertain:

1936	T = 1937 Jan. 31		T = 1937 Feb. 16	
	h m	° ′	h m	° ′
Dec. 2	12 34.0	— 7 9	11 53.3	— 5 47
6	12 48.8	8 5	12 6.8	6 44
10	13 4.1	9 1	12 20.6	7 41
14	13 19.7	9 54	12 35.1	8 36
18	13 35.8	10 44	12 50.0	9 31
22	13 52.0	11 32	13 5.4	10 22
26	14 8.9	—12 15	13 21.4	—11 12

The prediction is given for two assumptions, differing by 16 days, as to the time T of perihelion. The region, which is easily accessible in the morning sky, was explored without success by the writer on November 17. The theoretical brightness is increasing and the search should be continued.

Williams Bay, Wisconsin, November 20, 1936.

Notes from Amateurs

Cleveland Astronomical Society

The first meeting of the winter series was held in the Physics Building Auditorium of Case School of Applied Science, Friday evening, November 6.

Leslie C. Peltier, internationally known astronomer of Delphos, Ohio, was the speaker of the evening. Dr. J. J. Nassau, Director of the Warner & Swasey Observatory of Case School, introduced Mr. Peltier who chose as his subject, "How the Amateur Astronomer Works." He estimated that there were 10,000 homemade telescopes in the United States, but regretted that "nothing is being done with most of them." He called attention to the imporant work that amateurs can do in the study of variable stars. It is of interest to note that Peltier has contributed ten per cent of the total observations of variables in the world. Research of sun-spots and close attention of the surface markings of Jupiter, discovery of comets and study of the surface of the moon were other tasks he suggested. "Although the moon is comparatively close to us and objects the size of the capitol at Washington can be detected we do not know all there is to know about the moon," Peltier said. "We do not know whether the surface is of ash or cinder; we cannot explain the crater changes and no one has ever seen a meteor strike its surface."

The search for novae and observation of meteors were suggested for amateurs not possessing telescopes. "There is no particular thrill at the discovery of a new comet," he said, "the main reason is because you don't know at the time whether it is a new comet." The discovery occupies several hours, while the observer watches for movement of the body. Then it is days before verification is received and the observer learns whether another, perhaps in China, has sighted it five minutes before."

Peltier is a ready and fluent lecturer. During the time he was talking the audience was so quiet that the proverbial pin could have been heard if dropped. His personality is charming as is also his modesty when speaking of his discoveries. His eyesight is four times as keen as the average person's. Peltier is credited with having discovered five comets and two novae in addition to being the world's foremost variable star observer.

Don H. Johnston, *Recording Secretary.*

14 Lincoln Drive, Cleveland, Ohio.

ORION'S GREAT NEBULA
An Amateur Looks Into Space

One of the most interesting objects in the sky for observation by amateur telescope makers is the Great Nebula in the constellation Orion—a diffuse nebula of colossal size. This object is the supreme wonder of all celestial marvels. It is a stupendous mass of brilliance without definite form lying about 1,800 light years away, and occupying space equal to 1,500,000 times the distance from earth to sun. It is located at the end of Orion's sword, and is dimly visible to the naked eye as a faint blur. With good seeing, and 100 or higher magnification, it is a myterious and amazing sight. At first it looks like a patch of fog shining with a soft greenish white light. By closer attention one becomes conscious of a jet black cloud encroaching from the north side and producing a sharply defined border line between the light and dark areas.

The entire object is said to be cosmic dust mixed with molecules of gas, known

as nebulosity. The bright part is luminous because of energy radiated by nearby stars of high temperature and reflected from the cosmic material; and the dark part lies between us and the light-giving stars. The dark area appears to be as black as ink, and scattered over it are a number of stars that seem intensely bright in contrast. These stars are a very great distance this side of the black material—so far, in fact, that their light cannot be seen visually to be reflected from it.

The repulsive force—light pressure—of the sun, and other stars, on extremely fine particles of dust is said to be about ten times greater than their gravitational pull. This repulsive force drives these minute particles into space until other stars begin to act upon them. In this way great clouds of this material come to places of loose equilibrium and there they are held by counter forces. The greater part of this nebulosity, however, has not found a place of equilibrium but drifts along among the stars in irregular lacy strings and fleecy patches like drifting smoke left by a distant train.

One stops to wonder about the origin of this cosmic material, and then remembers that the sun loses about 250,000,000 tons of mass every minute by radiation into space—mass composed of particles, ions, electrons, neutrons, positrons, or whatever it is, in the character of energy, that the sun ejects into space. Naturally all the other stars in the universe are losing weight in much the same way, but at different rates. Capella, in Auriga, is said to radiate energy at the rate of thirty-one billion tons a minute. But whether this stray radiation—this starlight—is the source of "cosmic dust mixed with molecules of gas" is a quesion for a cosmogonist, and not for a groping amateur. Emitted mass that can be reckoned in "tons," however, must be something, and it must go somewhere. It may be the origin of cosmic dust—of nebulosity—and eventually of stars and galaxies.

The density of the Orion Nebula is extremely low. Some astronomers suggest that it is only about one-quadrillionth the density of air at sea level. This sounds as if it contains no matter at all, yet it is so large that it probably contains enough matter to make thousands of stars equal to the sun. The central bright portion is approximately twenty-five light years in diameter and is the most primitive form of matter known. It is agitated by the radiant energy of nearby stars of high temperature into violent currents that produce tremendous chaotic turmoil.

Enmeshed in the Nebula, but distinctly visible in the telescope, is the rare multiple star, Theta Orionis. This is the famous Trapezium. It is composed of four blue-white stars of 6, 7, 7½, and 8th magnitude, disposed in the form of a trapezium. Above and to the right of the trapezium are three very hot blue-white stars in a row spaced like a miniature belt of Orion.

A photographic plate, exposed many hours, directed toward almost any part of the constellation Orion reveals wisps and coils of lacy nebulosity indicating that nearly the entire constellation is enveloped in lumious cosmic dust. The longer the exposure the more extended becomes the irregular wispy threads of thin luminosity.

If clouds of cosmic dust, such as that which forms the Great Nebula in Orion, the North America Nebula in Cygnus, the Trifid Nebula in Sagittarius, and the nebulosity surrounding the stars of the Pleiades, engulfed the sun, its obscuring effect would cut off enough of the sun's light and heat to lower the earth's temperature several degrees. Who knows but that such obscuring matter may have surrounded the neighborhood of the sun on one or more occasions and was then driven by the action of the sun, Sirius, Procyon, Altair, Capella, and other nearby stars to some other part of space? And who knows but that while this nebulosity was in our part of space the Great Ice Ages occurred?

Astronomers, meteorologists, and geologists have been postulating causes of the Glacial Periods for a long time without agreeing,—probably because none of the causes seem to stand rigid scrutiny. That a variation of the sun's radiation to the earth was a contributing cause seems reasonable, but that this variation was due to the sun's having been a variable star does not. The idea of cold regions in space enveloping the earth (unless by nebulosity), or the effect of precession, or of continental uplift, seems like sheer imagination. But nebulosity screening radiation from the earth could have happened. The weak point is the small space between earth and sun. The answer to this objection is the density of the absorbing cloud and the length of its sojourn. The sun could have been surrounded by dense nebulosity and the earth's atmosphere affected by clouds and cold, causing the northern ice caps to creep far down into the now Temperate Zone.

The fact that diffuse nebulae are known only because they are in the neighborhood of galactic stars suggests the thought that the cosmic material of which they are composed may be scattered in space away from our Galactic System. When this material is repelled by galactic stars, there is reason to believe that much of it drifts away from the Galaxy and into the deeps of space. We know that some kind of material surrounds the earth beyond our atmosphere as evidenced by the aurorae, the Zodiacal Light, and the Gegenschein. Then there are the "stationary" calcium lines in the spectra of a great many galactic stars, indicating a thin cloud of calcium, sodium, and other elements not easily identified, known as the "Space Cloud," permeating the entire Milky Way System, and of course surrounding the sun and all the planets. Very little imagination is needed to suggest that similar matter is everywhere in extragalactic space.

There is no generally accepted hypothesis that nebulous matter—cosmic clouds —exists in external galactic space, but also there is no generally accepted evidence that it does not so exist. For all we know it may exist in unthinkable quantities where no light reveals it. And who knows but that this cosmic material, when spread throughout tens and hundreds of millions of light years of space, may deflect the short (blue) rays of light and thus slow down the frequency enough to cause the spectra of far distant galaxies to show a displacement of their lines toward the red end, which is the indication of recession. The farther away the external galaxy the more the shift of the lines toward the red. This accords with the foregoing view because the greater the distance of the object the more cosmic dust the light would have to pass through and thus the greater the retardation of the short rays. True, it has been demonstrated that there is no appreciable difference in the speed of red and blue rays of light traveling in space, but this demonstration was made on light from globular clusters in our own galaxy. These clusters average only about 70,000 light years distance; a very different story is possible when we go out into space ten million—or ten hundred million—light years.

One does not quetsion the rapid movement of far distant galaxies, but that these objects are all receding from us at extremely high speeds, some at rates greater than one-eighth the speed of light, as has been ventured, and still faster as distances increase—an increased speed of a hundred miles a second for each additional million light years of distance—is too much to believe, at least until some credible attractive or repelling force is conjectured, even if not proved. A universe that exploded unthinkable billions of years ago with such violence that it is *still increasing the speed* of distant galaxies, with scarcely a suppositional force to cause the explosion, or space that expands as fast as distant galaxies approach its limits, with no reasonable cause for the expansion nor explanation of how

space can expand, does not satisfy an inquiring amateur. If one believes, as this amateur does, that there are super-galaxies (galaxies of galaxies) and galaxies of super-galaxies to as many orders as you wish to count, the idea of an explosion, or of expanding space, becomes a mental nightmare.

Apparently there is nothing wrong with the spectra of these objects—the extraordinary shift toward the red is there—so something must happen to light in its long journey through the abyss of space. Maybe, as de Sitter suggests, light loses some of its energy in its long journey from its source, and is thus reddened by age. (Light becoming reddened in this way and the spectral shift toward the red end are the same phenomenon.) But how is it reddened? What happens to it? I do not know what gives the appearance or terrific recessional speed of distant spiral nebulae so I wonder if the scattering of the short rays of light—the zigzag drag—could produce it? That the red shift is due to something happening to light in its long journey seems plausible. The indicated stampede does not seem plausible.

A recent discovery is that of a galaxy in Boötis, two hundred million light years away, receding at 24,200 miles a second. Go far enough into space at the same accelerating rate and these objects would be receding faster than the speed of light—plausible only to a writer of "Amazing Stories."

The final solution of this question as well as the whole enigma of diffuse nebulae will take greater knowledge than we have at present. This ignorance, however, need not lessen our pleasure in viewing the Orion Nebula. The Orion is the "type" nebula of diffuse nebulae, but it is not the largest of its kind. The Looped Nebula in the Greater Magellanic Cloud is said to be more than two thousand times as great as the Orion Nebula, and the great dark nebula that splits the Milky Way from Cygnus to near the Southern Cross is so large—and its distance being unknown—that it is difficult to estimate its size.

San Francisco, California. J. B. Duryea.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editors may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

A Mechanical Explanation of Light and Related Phenomena

The generally accepted theory of light is that it is wave motion in a stationary medium called ether. There are many questions that are not answered by this theory and many phenomena that render it absurd. Some of the questions are the following:

(1) How can a medium be so rigid and elastic as to transmit an impulse through a distance of 186,300 miles in one second and yet so mobile and nonresistant as to allow free motion, even of a body consisting of the rarest gas, offering no more resistance to this than to a massive planet?

(2) Why do light waves travel in perfectly straight lines while sound waves, supposed to be similar, do not necessarily do so?

(3) If light and other related waves resemble sound waves in any sense whatever, what explanation is there for the following:

(a) The beam of light; (b) Polarization of light; (c) Refraction; (d) Aberration; (e) Diffraction; (f) The lateral nature of the wave motion discovered by recent investigation; (g) Interference of light from one source and non-interference from different sources; (h) The passage of thsee wave motions through certain forms of matter with little or no effect upon them; (i) Transformation of waves of one frequency into those of another frequency; (j) The quantum theorist's assertion that light waves come in bundles, resembling a bundle of darts, striking at different times, that is, waves in different phases but the same frequency?

Try to send a beam of sound through a room and leave that room in utter silence. A beam of light can be sent through a dark room leaving the room in utter darkness, yet that same beam, falling on a white surface in the next room, will illuminate that room. A beam of sunlight may pass through a lens of ice without melting it and may be made to melt metal on the other side of that ice lens.

The mechanics of light cannot be explained apart from rectilinear motion of propagation and motion of something beside the so-called wave, something, of course, that gives the effect of undulation or wave motion.

My theory is that all space is filled or permeated with particles extremely long with respect to their almost zero cross section (yet actually very short). These particles are moving at the velocity of light, 186,300 miles per second. They advance in perfectly straight lines without any deviation therefrom. Through every point in space these particles are passing in every one of the infinite directions, both ways. The lines undulate: they are in the shape of a wavy wire, so to speak. The waves travel only as the particles travel. The undulations may be any length (wave-length), from almost zero to the longest radio wave, or any combination of these wave-lengths at the same time. The undulations may be in any plane containing the moving line of particles.

These moving particles pass through matter without any hindrance to their velocity of travel, but the atoms of matter are capable of absorbing or transforming the wave-motion of the particles or imparting wave-motion to them, or of retarding somewhat the undulations.

Incidentally the atoms are elongated particles, revolving, when excited, about their central points, like a drum major's baton, in every conceivable direction.

With this mechanical set-up the various phenomena of light and the other kindred entities may be explained.

Rectilinear motion is of course obvious.

Transparency of certain substances to certain wave-lengths means that the atoms cannot absorb vibrations of those frequencies. The same substances may be able to absorb completely other wave-lengths; they are opaque to these.

Aberration is completely explained.

Polarization is inhibition of undulations in one general direction. Molecules of a crystal arranged in grill-like fashion would explain this. Nothing but undulations transverse to the line of advance could begin to explain polarization.

Reflection is the handing over of the undulations of particles moving in the direction of the angle of incidence to other particles moving from behind the reflecting surface at the angle of reflection. Refraction is a similar transfer of undulations. Neither is instantaneous but requires some part of the time of the passage of one wave. This is why the experiments of Michelson failed to detect the proper motion of the earth; the short beams (about 40 feet long) were reflected and refracted so many times that light interference was too large a scale to meas-

ure a fraction of a wave-length.

When light is diffracted, as in a beam passing through a narrow slit, vibrations are communicated laterally to other moving particles passing through the slit at the same time at small angles with the main beam, exciting these to the condition of light carriers. This is quite different from the common explanation that the waves spread as sound waves are known to do; sound waves spread through 180 degrees.

The "bundle of darts" idea is completely explained by this theory; each line of particles has its own phase. By the same token interference of light from one source (and not from different sources) is made clear; incident and reflected lines of particles have the same phase, therefore they can interfere.

Matter may absorb undulations of one frequency, and the absorbed undulations or vibrations may issue at the same time or later, as vibrations of other wave-lengths. This absorption and transformation is one of the most common of phenomena. It is probably due to the arrangement or composition or proper motion of the atoms or molecules.

Radioactive substances absorb waves of some length and transform the same into the vibrations that seem to emanate from such substances. The radioactive substances are certainly not the source of these vibrations nor of the energy the same represent, but merely transformers, so to speak. Possibly the waves absorbed are exceedingly short waves that science has not yet found the means to detect, and yet that flood all space.

Wave-lengths of the visible spectrum were the first to be recognized and measured, then infra-red and ultra-violet, later the X-ray, the cosmic ray, etc., and among the long ones, radio waves. The waves responsible for electricity and magnetism seem yet to be classified as to frequency.

The X-rays will penetrate certain thicknesses of matter but will be stopped by greater thicknesses. The cosmic ray will penetrate eleven feet of lead. It is doubtless stopped by greater thickness. Probably there are other rays, of shorter length than the cosmic ray, coming from distant space, that penetrate matter with great ease but still would be absorbed in matter of great thickness. It seems to be true that the larger the heavenly body (in the solar system at least) the higher its temperature, as for example the moon, the earth, Jupiter, and the sun.

In distant space there are vast expanses of nebulae, matter in exceedingly rare form but extremely active, excited to vibrations the frequency of which is almost infinite. In vast amounts these vibrations reach us through the medium of our moving particles as undulations that science cannot yet detect or measure. In a large, thick body of matter some of these undulations can be absorbed and transformed into internal heat.

The greater the size and mass of a heavenly body the greater its capacity to absorb this fugitive energy. Absorption would be as the cube of the diameter for equal density, but radiating surface is as the square of the diameter. As a rough and tentative calculation assume that the earth receives and radiates 1½ units of fugitive energy from space in a unit of time and that its temperature is 200° C, absolute. This is about the temperature at the poles, where the sun's heat and the kneading influence of the moon are practically zero. The sun would receive and radiate 330,000 times as much, or 495,000 units. By Newton's law of radiation (proportional to absolute temperature) the sun would radiate x/200 times as much as the earth per unit of surface and 900/8, squared, times this, by reason of relative surfaces, or 63x, x being the absolute temperature of the sun. Equating this to 495,000 gives about 7100° as the absolute temperature of the sun at the poles,

where Jupiter's kneading influence is nil. The temperature of Jupiter on the same basis is computed to be about 820°, absolute.

In my theory all energy and power has its source in these swiftly-moving, impinging, undulating particles. All space is dynamic, but only certain conditions serve to transform the power into usable form. The atomic power theory has no grounds for its assumptions in anything that goes on in the earth. To assert that the interior temperature of the sun is 52,200,000°, when it is known to have a surface temperature near 10,000°, is fantastic in the extreme. Why assert that action takes place in the stars that cannot in any degree be approached in the earth?

It has recently been asserted that gravitation acts with the speed of the velocity of light. In 1908 I published an article in which I set forth the theory of light here described and the theory that gravitation is the result of the impinging of the particles that carry light on the atoms of matter, driving them together. No doubt gravitation does act with the speed of light, but the only example where it would affect the motion of heavenly bodies is in a satellite of great eccentricity.

Space forbids discussion of gravitation or of electricity and magnetism and their purely local character.

EDWARD GODFREY.

General Notes

Maud Worcester Makemson has recently been appointed chairman of the department of astronomy and director of the observatory at Vassar College, Poughkeepsie, New York, on the Alumnae Maria Mitchell Foundation.

Mr. C. W. Elmer, well known in astronomical circles as a capable and energetic amateur astronomer, recently elected secretary of the American Association of Variable Star Observers to succeed the late William Tyler Olcott, and Mr. R. S. Perkins have become associated with the William Mogey and Sons Company in the manufacture of telescopes. The reorganized company has offices at 154 Nassau street, New York City, and factory at Plainfield, New Jersey.

The Rittenhouse Astronomical Society, of Philadelphia, held a meeting on Friday, November 13, in the Hall of The Franklin Institute, Twentieth Street and the Parkway. The program was "Siberia: Eclipse and Meteor Craters," illustrated with slides and motion pictures taken by the speaker, Dr. Clyde Fisher, Curator of the Hayden Planetarium of the American Museum of Natural History.

On Saturday afternoon, November 21, a visit of the members of the society to the Westinghouse plant at Lester, Delaware County, to inspect the work on the mounting of the 200-inch telescope was made.

A. CLYDE SCHOCK, *Secretary.*

A Solar Halo.—On June 23, this year, we observed a sun halo, which, when we first noticed it at 11:45, E.S.T., was complete and brilliantly colored. Holding thickly folded paper between our eyes and the sun, we watched the awe-inspiring sight at intervals for the three hours during which it was visible, after which, having lost none of its brilliance, it disappeared in the clouds that obscured the sun.

At one time an arc of a second more faintly colored ring was seen to the southwest at a distance of about 22° from the inner ring. The atmosphere between the halo and the sun was of a peculiarly luminous color; deeper than the

blue of the sky—indeed almost purple and, ascending from the west, was a fan-shaped pillar of cloud which wheeled and shifted within itself, but did not rise to the altitude of the sun until the afternoon was well advanced.

There was a storm with a northeast gale and two inches of rain on the next day, June 24. The halo may have presaged this storm.

East Sandwich, Massachusetts. MRS. WILFRED TAYLOR.

Occultation of Jupiter, December 14, 1936

Central Standard Time, P.M.

Long. \ Lat.	Immersion 48°	Immersion 40°	Immersion 32°	Emersion 48°	Emersion 40°	Emersion 32°
120°	2:37	2:29		3:42	3:51	
110°	2:51	2:48	2:46	4:02	4:12	4:17
100°	3:04	3:06	3:09	4:17	4:27	4:30
90°		3:21	3:30		4:35	4:36
80°		3:34			Below Horizon	

The above table gives for a number of places in the United States the times of immersion and emersion of an occultation of Jupiter which is to occur mostly in daylight with the planet about eleven degrees east of the sun. Since there will be only a small difference (about 5′) between the declination of the two, it should be possible to find Jupiter by pointing a telescope at the sun and waiting approximately forty-four minutes. The altitude will be rather low at the eastern stations listed above but should be favorable enough at the western ones. This phenomenon should be of interest to those who like to observe occultations in which the occulting body itself is invisible. JACOB HERMANN.

436 N. Lake Street, Madison, Wisconsin.

OBITUARY

Friedrich Küstner, the Dean of German astronomers, died on October 15. He was eighty years of age. Küstner was Director of the Bonn Observatory until 1926 when he retired and moved to the little town of Mehlem, about ten miles south of Bonn. He was famous for his two star catalogues, unsurpassed in accuracy and in thoroughness. With the 14-inch telescope of the Bonn Observatory he carried out an accurate set of determinations of radial velocities of the brighter stars, and with the same instrument he made a determination of the solar parallax by observing the radial velocity of Arcturus. His most important discovery was that of the variation of latitude which he announced in 1888, nearly fifty years ago. F. S.

Book Reviews

Geschichte und Literatur des Lichtwechsels der Veränderlichen Sterne, by R. Prager.

This octavo volume of 354 pages is the result of work done at the Berlin-Babelsberg Observatory although it is issued under the auspices of the Astronomische Gesellschaft. It is the second volume in the series and contains the data pertaining to the variables found in the twenty-nine constellations alphabetically arranged from Cygnus to Ophiuchus, both inclusive. The literature relating

to 1564 stars is included. References are given to all material relating to these stars published in the interval 1916 to 1933, and to some items published in 1934 and 1935.

A mere glance at this volume gives one the impression of the vast amount of labor involved in the preparation of it. It elicits the gratitude of all who have to do with variable stars because it affords a ready and convenient compendium of the extensive literature now extant in this field.

La Planète Mercure et la Rotation Des Satellites, by E. M. Antoniadi. (Gauthier-Villars & Cie, Paris. 18 fr.)

This work is planned as the first in a series of seven pamphlets which the author has in preparation in relation to the planets. The discussion is both from the historical and astrophysical point of view. For historical data the author made a careful study of the source materials in the National Library of Paris, in the writings of the Greek philosophers and Latin authors, and also in the various works of modern writers in French, English, German, and Italian since the 17th century. He, therefore, has been able to publish a considerable number of historical facts which one does not ordinarily find in a work on astronomy. On the astrophysical side the author has been an assiduous observer of the planets since 1909, having had the privilege of using the large telescope of the Observatory at Meudon for the purpose.

It was discovered by Schiaparelli in 1889 that, except for small librations, Mercury always presents the same face to the sun. The author has been able to confirm this conclusion through his work at Meudon. Furthermore, through observations of markings on the satellites of Jupiter he has been led to the conclusion as developed in the present work, that all the satellites, except the very distant ones of Jupiter and Saturn, present always, as does the moon, the same face to their primaries.

Veröffentlichungen der Universitätssternwarte zu Berlin-Babelsberg, Vol. XI, Part 2.

This is an octavo volume of eighty-eight pages. It is devoted to a photometric study of the brighter stars by means of photography. The discussion of the observations, represented in this volume, was made by Dr. A. Brill. A large amount of significant material is presented here in the usual clear and finished form of the publications from this observatory.

Die Entwicklung des Weltalls, by Karl Lessman. (Published by Otto Hillman, Leipzig.)

The above is the title of a pamphlet of twenty-six pages presenting a critical study of the evolution of the universe. Judging from the tenor of a few paragraphs which the writer has taken time to translate, the discussion is clear, thorough, and stimulating. The author intimated in a letter that his "ideas dissent widely from present opinions on this subject," which means that, instead of merely reviewing accepted facts, an attempt is made to contribute to a better understanding of the problems of cosmogony which are so baffling because of their magnitude. The text is in the German language, as one would of course infer from the title.